Marine Fisheries REVIEW

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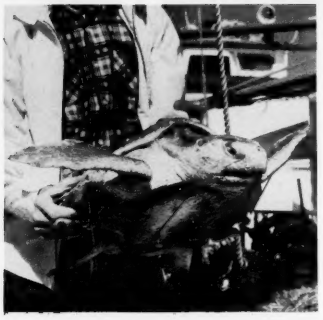
Headstarting Marine Turtles

Marine Fisheries REVIEW



On the cover: A young Atlantic ridley, *Lepidochelys kempi*. Photograph by Larry H. Ogren.

Articles — *March 1981, 43(3)*

A Survey of Chlorinated Hydrocarbon Residues in Menhaden Fishery Products — *Virginia F. Stout, Clifford R. Houle,* and *F. Lee Beezhold* 1

Acylation of Fish Protein: Effect of Reaction Conditions on Products — *Kang-Ho Lee, Herman S. Groninger,* and *John Spinelli* 14

Radio Tracking Juvenile Marine Turtles — *Robert E. Timko* and *David DeBlanc* 20

Departments

NOAA/NMFS Developments — *National Climate Plan, Fish Navigation,* and *Tagged Albacore* 24

Foreign Fishery Developments — *Japan's Fish Use and Fishermen's Income, Ecuador's Herring Exports, Netherlands Antilles' Fish Sales, Japan's Supermarkets and Fish, France Checks Indian Ocean EEZ,* and *Iceland-U.S. Fish Trade* 26

Publications — *NMFS Scientific Publications, Tropical Fisheries Technology, Dangerous Marine Species, FAO* and *UNESCO Reports, Commercial Fishing Basics, Eel Culture, Squid Fishing Areas,* and *PRC Fisheries* 30

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A Survey of Chlorinated Hydrocarbon Residues in Menhaden Fishery Products

VIRGINIA F. STOUT, CLIFFORD R. HOULE, and F. LEE BEEZHOLD

Introduction

Menhaden (*Brevoortia tyrannus* and *B. patronus*) is the largest volume (but probably the least-known) fishery in the United States because it is not used directly as food for humans. Before Europeans arrived in the Western Hemisphere, menhaden played an active role in American Indian agriculture. Historians state that the Indian Squanto showed the colonists of New England how to catch and use these fish when they schooled inshore in the springtime. A fish was placed in every hill along with the seeds of corn to provide food for the heavily feeding plants, an early example of organic gardening. Future American farmers who did not follow the Indians' lead eventually found the soil too improverished to sustain continuous growth of corn, cotton, and tobacco, all of which place heavy demands on the nutrients in the soil.

Menhaden is an oily fish, and, shortly after the War of 1812, menhaden oil found use as a substitute for whale oil in lamps. Autolysis (self-digestion) was the original method for reducing the fish into oil. When cooking was introduced into the reduction process, the leftover cooked flesh was sold as fertilizer. By the 1880's, Europeans were adding fish meal, the dried residual flesh, to animal feeds, a practice adopted in the United States only after World War I.

Since 1935, fish meal has become too valuable for use as fertilizer. Virtually all menhaden meal is now used in animal feed, indirectly an important source of protein for humans. In the years 1971-75, menhaden constituted more than 40 percent by weight of all fish landings in the United States (Robinson, 1977).

Few people are aware of the contribution of menhaden products to the human diet. The oil is a common raw material processed for use in margarine and shortening in many countries, but it has not been used for that purpose in the United States since 1951 (Stansby, 1973). Poultry feeds often contain up to 5 percent menhaden meal as a source of high quality protein as well as unknown growth factors. Menhaden oil also is used in animal feed as a source of calories.

Starting in 1969, the fishing industry became aware that a class of chemicals called chlorinated hydrocarbons were accumlating in menhaden oil in much the same way as they were in agricultural products and freshwater fisheries. The insecticide DDT[1], which had prevented the typhus and plague epidemics after

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*ABSTRACT — Menhaden is the largest volume but, because it is rarely consumed by humans, the least-known fishery in the United States. Oil from menhaden is a component of animal feeds and after processing, in some countries, of margarine and shortening. Menhaden meal is a source of protein and unknown growth factors in poultry feeds. We have determined the chlorinated hydrocarbon content of whole menhaden (*Brevoortia tyrannus *and* B. patronus*) and its reduction products: menhaden meal, oil, solubles, and stickwater, in the 9 years 1969-77. We analyzed 610 samples for ΣDDT (1,1,1-trichloro-2,2-bis(p-chlorophenyl) ethane, DDT; and its metabolites 1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene, DDE; and 1,1-dichloro-2,2-bis(p-chlorophenyl)ethane, TDE), 314 samples for PCB's (polychlorinated biphenyls), and 253 samples for dieldrin (1,2,3,4,10, 10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8, 8a-octahydro-1,4:5,8-endo-exo-dimethanonaphthalene) and endrin (the endo-endo isomer of dieldrin). Both the arithmetic means and the high values for chlorinated hydrocarbons decreased in most types of samples from most areas over the period studied. Nonetheless, statistical analyses of the 541 data on menhaden oils using the F-test and Scheffe's method for multiple comparison (s-method) only partially confirmed the hypothesis that chlorinated hydrocarbon levels were decreasing with time. Comparisons among the four areas of the menhaden fishery showed significant differences in levels in oils in some years. These differences probably related to variations in size, age distribution, and life history of sample groups.*

[1]Abbreviations used in this manuscript: DDT = 1,1,1-trichloro-2,2-bis(*p*-chlorophenyl) ethane; DDE = 1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethylene; TDE = 1,1-dichloro-2,2-bis (*p*-chlorophenyl) ethane; ΣDDT = DDT and its metabolites DDE and TDE; and PCB's =polychlorinated biphenyls.

World War II, was the first such problem chemical. Early in the 1970's, an industrial chlorinated hydrocarbon group called polychlorinated biphenyls (PCB's) was similarly identified in menhaden oil. PCB's boil at high temperatures, do not burn or degrade chemically, and possess excellent electrical insulating properties. PCB's became widely distributed in the environment from uses in water-resistant coatings, marine lubricants, and transformers and capacitors. During the past decade, other chlorinated hydrocarbon insecticides, including toxaphene, chlordane, mirex, kepone, endrin, and dieldrin have also been identified in menhaden oil. All these chlorinated hydrocarbons have common properties. They are resistant to degradation both by chemicals and by the environment. They are insoluble in water and highly soluble in oil and fat. They accumulate in fatty tissues of organism both at the beginning of the food chain and at the end, in plankton and in carnivores, in sharks and in man. Unfortunately, they are also toxic to a variety of organisms besides insects.

Over the the past 20 years, numerous authors have documented the damaging effects of chlorinated hydrocarbons on the environment. Rachel Carson (1962) described in depth the effects of DDT accumulation. Burdick et al. (1964) correlated the death of lake trout fry with elevated concentrations of DDT in the eggs. Kuratsune et al. (1972) reported about the PCB-contaminated rice bran oil that caused the 1968 epidemic of the condition called Yusho in Japan. Another incident related to contaminated rice bran oil occurred in Taiwan in 1979[2]. Several episodes of poor hatchability and deformities in chickens in the United States occurred when PCB's leaked into fish meal during pasteurization (Cecil et al., 1972). Aulerich et al. (1973) determined that mink, fed Lake Michigan coho salmon, failed to whelp because of the high level of PCB's in the fish. Dieldrin came to the fore in 1974 when high levels of dieldrin in meat products were traced back to soybean foots accidentally added to animal rations. (Soybean foots, the colored and odoriferous substances removed from soybean oil during alkali refining, are considered inedible and normally are directed to industrial uses. Furthermore, dieldrin was present in the foots at a concentration that was unexpectedly high, because dieldrin was not applied directly to soybean plants. Dieldrin did find widespread use in the control of insect pests in corn, and soybeans often follow corn in the usual rotation of crops. Presumably dieldrin was absorbed by the soybean plants from the soil either directly through the roots or indirectly by evaporation and subsequent transpiration into the leaves.)

The continuing problems of chlorinated hydrocarbon contamination of foodstuffs for both animal and human consumption led to a variety of regulatory actions throughout the world. The U.S. Food and Drug Administration established an adminstrative guideline of 5 ppm (parts per million) for ΣDDT in the edible portion of fish (the only product of marine origin for which a DDT guideline was ever established). The tolerance for dieldrin in fish oil was set at 0.3 ppm, an indication of the greater toxicity of this compound. Temporary PCB tolerances were established in 1974 (Schmidt) at 5 ppm in the edible portion of fish, 2 ppm in animal feed components including fish meal and oil, and 0.2 ppm in finished animal feed. Sweden banned DDT in the late 1960's as did the United States in 1972. The Japanese were the first to stop manufacture and use of PCB's because of the 1968 Yusho episode which affected more than 1,000 people (Kuratsune et al., 1972). PCB usage in the United States was restricted in stages. Currently, PCB's may be used legally for only a few specialty purposes in the United States.

When this project began in 1969, fish from the Great Lakes were being seized for excess ΣDDT and the possibility of elevated levels in menhaden oil was of great concern to the industry. Menhaden oil is used in paints and lubricants, but is more valuable as a component of animal feeds. Initially we wanted to determine the levels of ΣDDT present in menhaden fishery products from various geographical locations. In addition, if elevated levels were found, we wanted to investigate methods for removing ΣDDT, especially from menhaden oil. Fish oil contains all the chlorinated hydrocarbons initially present in the fish, undiluted by the protein and water. Obviously the oil would contain higher concentrations of the chlorinated hydrocarbons than either the original fish or the other reduction products: Meal and solubles. Our studies (Stout et al., 1970) showed that removal of chlorinated hydrocarbons was not practical except under the conditions used for refining fish oil for production of margarine and shortening.

Subsequent work concentrated on determining the chlorinated hydrocarbon levels, initially ΣDDT, in samples from throughout the fishery. In 1971, we first included PCB's in our investigations. We added dieldrin and endrin analysis to our regimen in 1974 when a tankcar of menhaden oil was detained by regulatory officials, because the oil contained more than 0.3 ppm dieldrin. For historical perspective, we assayed the dieldrin content of some of our older samples as well.

This paper reports our findings on ΣDDT, PCB's, dieldrin, and endrin in whole menhaden and menhaden meal, oil, and solubles, from all areas of the fishery in the years 1969-77.

Materials and Methods

Atlantic menhaden, *Brevoortia tyrannus,* occurs along the Atlantic coast from Maine to Florida; Gulf menhaden, *B. patronus,* occurs in the Gulf of Mexico (Fig. 1). For those unfamiliar with fish reduction, a brief description will serve to define the substances studied in this paper.

[2]Anonymous. 1980. PCB widespread poisoning incident in Taiwan reported. Food Chem. News, Jan. 7, p. 23.

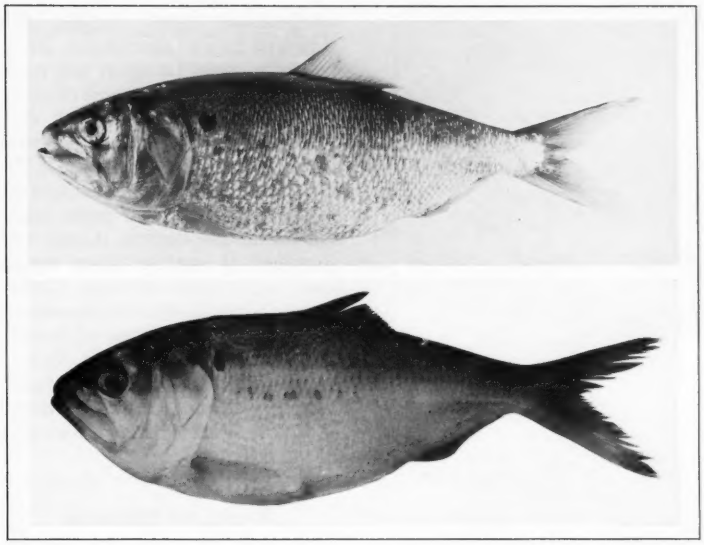

Figure 1.—Atlantic menhaden, *Brevoortia tyrannus,* fork length 25 cm (top). Gulf menhaden, *Brevoortia patronus,* fork length 27 cm (bottom). Photographs by J. Reintjes.

Whole fish are heated with steam in a large cooker and transferred to a press. The solid portion or presscake is dried to give fish meal. The liquid, which is expressed by the press, is centrifuged to separate the fish oil from the aqueous fraction, the stickwater. Evaporation of water from the latter yields solubles, which are sometimes sprayed onto the presscake prior to drying. Reduction plants cooperated in collecting samples from all regions of the fishery (Fig. 2). Fish were obtained just as they were being unloaded and the collection site noted. Collection of samples of menhaden meal, oil, and solubles was timed so that the samples of products represented the same fish as those from which the samples of fish themselves had been drawn. Obviously, this system was only approximate.

Fish were wrapped in aluminum foil and frozen at the time of collection. Solubles and oil were placed in glass bottles with aluminum foil or Teflon[3] lining the lids. Samples of meal were stored in double brown paper bags which contained no contaminating substances. Bottles, bags, and aluminum foil were shipped to all samplers to assure uniformity of receivers. Bottles were washed and baked at 260°-270°C before shipment.

After shipment of the frozen samples to this center, the fish were partially thawed, ground whole, mixed thoroughly, and stored in aluminum tubs sealed with tape at -18°C until analysis. Meals were ground in a meat grinder to break up scales and bones to provide a more homogeneous sample.

Chlorinated hydrocarbon analysis was evolving during the course of these studies. For the 1969 samples, the AOAC method for determination of chlorinated pesticides in nonfatty foods (Horowitz, 1970a) was used for fish and meal by adjusting the sample size to limit the oil content to 2 g, and adding water to make a total water volume of 80 ml. The oil was analyzed by extending the backwash procedure of Porter et al. (1970) of the AOAC method for fatty foods (Horowitz, 1970b). Oil (3 g), diluted to 15 ml with petroleum ether, was extracted with 30 ml of acetonitrile saturated with petroleum ether. The acetonitrile fraction was backwashed with 15 ml of petroleum ether. Five additional 30 ml portions of acetonitrile were shaken successively with the two petroleum ether solutions. This extensive partitioning process was necessary to obtain quantitative extraction of the chlorinated hydrocarbons from the fish oils and to separate them from interfering substances present in high concentration in the oils. The combined acetonitrile fractions were treated with 2 percent (weight/volume) aqueous NaCl and 100 ml of petroleum ether in the usual manner (Stout, 1978).

In all later years, the procedures of Reinert (1970) were used, because they gave cleaner extracts of marine fishery samples; Stout and Beezhold (1979) detailed our methods. The technique for fish oil was especially efficient for samples of marine origin which form intractable emulsions during the AOAC extraction procedure.

PCB separation from ΣDDT was introduced in 1971. Consequently, in samples from 1969 and 1970, part of the PCB's was quantitated as ΣDDT because of the overlap between the gas chromatographic peaks of certain components of PCB's and the DDT family. Although no effort was made to correct for PCB interference, the levels of ΣDDT were high enough at that time that the data give a fairly accurate indication of the extent of ΣDDT contamination. Ironically, by the end of the study 5 years after DDT was banned, the levels of ΣDDT had decreased so much that the small gas chromatographic peaks of DDE, TDE, and DDT were sometimes obscured by unidentified substances.

[3]Mention of trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Figure 2.—Areas of commercial menhaden fisheries and location of menhaden plants participating in the survey of cholorinated hydrocarbons.

For dieldrin and endrin analyses the alkaline saponification technique of Reinert (1970) was used. This procedure eliminated the contaminants remaining in extracts prepared by the AOAC method (Horowitz, 1970a).

Extracts were quantitated by electron-capture gas chromatography with a titanium-tritide detector. Details of our quantitation procedures have been published (Stout, 1980). The quantifiable limit for DDE, TDE, and DDT was 0.01 ppm in fish, meal, solubles, and stickwater and 0.05 ppm in menhaden oil. The quantifiable limit for PCB was 0.05 ppm in fish, meal, solubles, and stickwater, and 0.25 ppm in the oil. For dieldrin and endrin, the limit was 0.005 ppm in fish and meal and 0.01 ppm in the oil. Residue values were calculated on the basis of μg chlorinated hydrocarbon per gram wet tissue or parts per million (ppm).

The data are tabulated by areas of commercial menhaden fishing (Dryfoos et al., 1973) (Fig. 2). Along the Atlantic coast, the New York and New Jersey areas were combined into the Middle Atlantic area, and the North Carolina area of Dryfoos et al. (1973) was designated as the South Atlantic area. Data for all plants in the fishery in the Gulf of Mexico were combined. In every area, grouping relates to the location of the reduction plant where the samples were collected. In earlier years, the Atlantic menhaden fisheries rarely overlapped. With the introduction of shipboard refrigeration, vessels extended their territories into adjacent areas, but in tabulating data, no effort was made to segregate samples by area of catch.

The goals of the project and, therefore, the types of relevant samples, evolved over the years. The fishery declined for a time because the fish disappeared from some areas. Furthermore, collection, storage, and shipment of samples from remote areas were often difficult. Consequently, data for all contaminants are not available for all types of samples from all areas in every year. Table 1 summarizes the type of menhaden samples collected and the chlorinated hydrocarbons determined in each area of the fishery by year.

Results and Discussion

DDT and its metabolites

Overall, the ΣDDT levels declined in all products in all areas from the beginning of this survey in 1969 until the last year, 1977. Initially, the levels of ΣDDT were highest in all types of samples from the Middle Atlantic area (Fig. 2). In 1969, fish contained 0.966 ppm; meal, 0.399 ppm; and oil, 5.93 ppm ΣDDT. By 1976, the last year in which fish were collected, however, the concentration in fish in the Gulf of Mexico area (0.504 ppm) was three times that in the Middle Atlantic area (0.163 ppm). Although the concentration of ΣDDT in fish from the Gulf of Mexico declined between 1970 and 1974, the 1976 level exceeded that in 1970 (0.402 ppm), the first year in which fish were collected from the Gulf fishery. Since the seven samples of menhaden oil from the 1976 fishery in the Gulf of Mexico did not show a similar marked increase in ΣDDT level and the 16 samples of oil from the 1977 season contained less ΣDDT than in any previous year, the elevated level in the four 1976 fish samples may reflect a localized problem rather than a general trend. In all types of samples from the Middle Atlantic area, the levels of ΣDDT declined substantially during the 9 years of the survey. Similar, though less

Table 1.—Types of menhaden samples collected and chlorinated hydrocarbons analyzed by area and year.

Area	Type of chlorinated hydrocarbon			
	ΣDDT	PCB	Dieldrin	Endrin
Middle Atlantic				
1969	FMO	F[1]	O	O
1970	—	—	—	—
1971	FMO	FMO	O	O
1972	FMOS	FMOS	O	O
1973	FMOS	FMOS	O	O
1974	FMOS	FMOS	MO	MO
1975			MO	MO
1976	F O	F O	F O	F O
1977	O	O	O	O
Chesapeake Bay				
1969	MO		O	O
1970	FMO	M[1]		
1971	FM	FM		
1972	MOS	MOS	O	O
1973	MOS	MOS	O	O
1974	FMOS	FMOS	MO	MO
1975			MO	MO
1976	F O	F O	F O	F O
1977	O	O	O	O
South Atlantic				
1969	M		O	O
1970	FMO			
1971	FMO	FMO	O	O
1972	—	—	—	—
1973	MOS	MOS	O	O
1974	MOS	MOS	MO	MO
1975	—	—	—	—
1976	F O	F O	F O	F O
1977	O	O	O	O
Florida				
1970	FM	M[2]		
Gulf of Mexico				
1969	M		O	O
1970	FMO			
1971	—	—	—	—
1972	FMOSSw	FMOSSw	O	O
1973	FMOS	FMOS	O	O
1974	FMOS	FMOS	MO	MO
1975			MO	MO
1976	F O	F O	F O	F O
1977	O	O	O	O

F = whole fish, M = meal, O = oil, S = solubles, Sw = stickwater, — = no samples of any type collected in that year. Blanks indicate certain types of samples not collected or not analyzed for the indicated contaminant.

[1] One sample.

[2] Two samples.

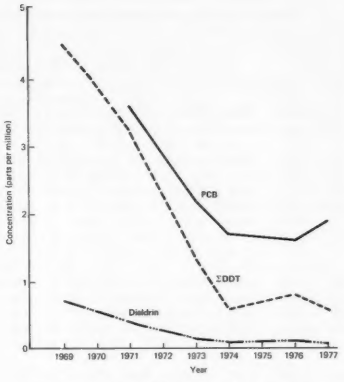

Figure 3.—Chlorinated hydrocarbon levels in oil from menhaden taken from the South Atlantic fishery, 1969-77.

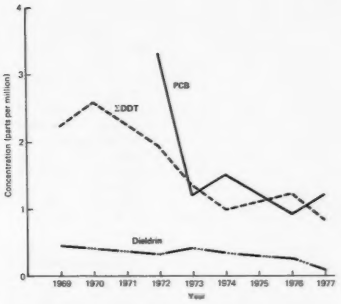

Figure 4.—Chlorinated hydrocarbon levels in oil from menhaden taken from the Gulf of Mexico fishery, 1969-77.

dramatic, declines occurred in other areas as well, as shown graphically for menhaden oil from the South Atlantic fishery in Figure 3. The trend in samples from the Gulf of Mexico was more erratic (Fig. 4). Perhaps that behavior related to the lower initial levels in the area. Alternatively, the reservoir of ΣDDT in the Mississippi River drainage may be greater or its release more readily influenced by fluctuations in precipitation and other conditions. The data for ΣDDT in fish, meal, oil, solubles, and stickwater are summarized in Tables 2, 3, 4, and 5, respectively. Also shown are the relative proportions of DDT and its metabolites DDE and TDE. The most consistent change was a decrease in the parent compound DDT in menhaden oils. In oils from the Middle Atlantic states and the Gulf of Mexico, this decrease was accompanied by an increase in the proportion of TDE, the metabolite formed by a reductive process, involving replacement of one chlorine atom by a hydrogen atom. Since DDT usage declined in the late 1960's and was banned entirely in 1972 (and DDT does degrade slowly), decreases both in the amount of ΣDDT and the proportion of DDT might be anticipated. Also to be noted was the increased proportion of DDE in menhaden meal (Table 3). This might result from degradation of DDT to DDE during the reduction process. Iron and other chemicals catalyze the dehydrochlorination of DDT to DDE. This is the typical terrestrial mode of degradation of DDT, in contrast to the anaerobic degradation of DDT to TDE, which occurs in the marine environment in the presence of microorganisms. Dehydrochlorination may occur more rapidly at the elevated temperature of the meal drier.

PCB, the Industrial Chemicals

The initial findings about PCB's were most startling: 6.59 ppm in fish and 9.9 and 13.4 ppm in two samples of oil. Further analyses confirmed that nearly all samples contained much higher concentrations of PCB's than ΣDDT. Although PCB's were introduced a decade before DDT, PCB's were not identified as environmental pollutants until long after ΣDDT, because of the complexity of PCB analysis. The method for analyzing chlorinated hydrocarbons, gas chromatography with an electron-capture detector, produces one or more peaks for each individual compound present. PCB's are a mixture of up to 210 compounds resulting from the chlorination of biphenyl. The PCB's commonly found in samples of marine origin produce a series of more than ten broad peaks, several of which overlap the three narrow peaks produced by the DDT family, i.e., DDE, TDE, and DDT. Once recognized as ubiquitous environmental pollutants, PCB's still presented the challenge of developing a satisfactory method for separation from the DDT family. Furthermore, the electron-capture detector is less sensitive to

Table 2.—ΣDDT in menhaden fish by area (1969-76).

Area and year	No. of samples (total no. of fish)	Mean (ppm)	SD	Low (ppm)	High (ppm)	Percent of ΣDDT as DDE	TDE	DDT	PCB / ΣDDT ratio
Middle Atlantic									
1969	2 (24)	0.966	0.161	0.852	1.08	23.6 ± 14.8	58.4 ± 9.8	18.1 ± 4.9	[1]3.20
1971	1 (12)	1.59				48.8	40.3	10.8	2.04
1972	5 (88)	0.820	0.128	0.644	0.944	42.9 ± 7.9	43.1 ± 5.4	14.0 ± 3.8	4.46 ± 1.83
1973	5 (81)	0.569	0.125	0.400	0.722	46.9 ± 11.3	38.7 ± 5.9	14.4 ± 6.3	2.73 ± 1.01
1974	4 (75)	0.283	0.042	0.237	0.334	43.8 ± 7.8	45.2 ± 5.7	11.0 ± 3.5	3.64 ± 0.95
1976	4 (73)	0.163	0.156	< 0.02	0.336	35.2 ± 9.9	52.9 ± 11.7	11.8 ± 2.3	4.30 ± 0.71
Chesapeake Bay									
1970	6 (61)	0.795	0.826	0.250	2.18	46.7 ± 17.0	34.9 ± 10.1	18.4 ± 10.3	n.a.
1971	3 (28)	0.440	0.165	0.312	0.626	38.0 ± 12.7	32.2 ± 2.8	29.8 ± 10.3	0.92 ± 0.06
1974	3 (58)	0.069	0.031	0.037	0.098	40.6 ± 2.3	50.6 ± 7.0	8.8 ± 9.0	3.96 ± 1.38
1976	2 (31)	0.090	0.047	0.056	0.123	44.6 ± 4.9	40.2 ± 8.7	15.2 ± 3.8	2.94 ± 0.36
South Atlantic									
1970	21(177)	0.189	0.176	0.026	0.853	45.6 ± 17.4	22.8 ± 13.4	32.5 ± 10.1	n.a.
1971	6 (72)	0.282	0.192	0.086	0.539	37.0 ± 4.9	33.1 ± 12.2	30.1 ± 10.4	2.56 ± 2.40
1976	2 (36)	0.158	0.155	0.049	0.268	34.4 ± 9.1	50.8 ± 8.3	14.8 ± 0.7	4.62 ± 3.37
Florida									
1970	10 (75)	0.071	0.080	0.019	0.283	45.9 ± 15.5	12.8 ± 20.8	41.7 ± 12.0	[1]1.25
Gulf of Mexico									
1970	32(100)	0.402	0.220	0.145	1.12	27.7 ± 10.3	39.9 ± 4.7	32.2 ± 9.8	n.a.
1972	3 (42)	0.272	0.047	0.229	0.322	34.0 ± 11.6	35.6 ± 4.3	30.5 ± 9.9	1.86 ± 1.11
1973	8(155)	0.265	0.038	0.197	0.306	29.3 ± 10.8	39.3 ± 7.7	31.4 ± 6.7	1.28 ± 0.28
1974	9(184)	0.198	0.064	0.085	0.314	22.9 ± 9.0	52.8 ± 20.6	24.4 ± 15.1	1.85 ± 0.87
1976	4 (77)	0.504	0.043	0.460	0.563	28.2 ± 3.4	37.8 ± 2.8	34.1 ± 1.0	0.81 ± 0.11

[1]One sample only.
When year omitted, either samples not obtained or analyses not performed.
n.a. = PCB not analyzed.

Table 3.—ΣDDT in menhaden meal by area (1969-74).

Area and year	No. of samples	Mean (ppm)	SD	Low (ppm)	High (ppm)	Percent of ΣDDT as DDE	TDE	DDT	PCB / ΣDDT ratio
Middle Atlantic									
1969	6	0.399	0.098	0.324	0.591	39.6 ± 10.0	53.3 ± 9.7	7.2 ± 2.4	n.a
1971	1	0.811				61.9	34.8	3.3	1.86
1972	5	0.273	0.041	0.226	0.334	53.8 ± 9.5	40.9 ± 5.0	5.3 ± 4.8	3.94 ± 1.02
1973	5	0.152	0.041	0.083	0.190	52.4 ± 10.7	34.7 ± 10.6	12.9 ± 6.4	3.26 ± 1.16
1974	4	0.104	0.025	0.083	0.135	55.5 ± 11.6	44.5 ± 11.6	0 ± 0	4.72 ± 2.26
Chesapeake Bay									
1969	2	0.228	0.022	0.213	0.244	26.0 ± 0.4	64.8 ± 13.3	9.2 ± 12.9	n.a.
1970	17	0.364	0.277	0.080	0.993	52.0 ± 15.2	30.6 ± 6.9	17.4 ± 10.2	[1]0.82
1971	3	0.304	0.046	0.255	0.347	46.8 ± 4.5	36.0 ± 2.9	17.2 ± 3.2	1.29 ± 0.28
1972	4	0.226	0.040	0.166	0.250	40.1 ± 5.0	31.1 ± 5.0	28.8 ± 1.2	2.03 ± 0.41
1973	3	0.176	0.027	0.148	0.201	46.9 ± 3.8	36.4 ± 5.0	16.6 ± 7.4	1.97 ± 0.39
1974	5	0.067	0.006	0.058	0.075	55.3 ± 5.2	44.7 ± 5.2	0 ± 0	3.58 ± 0.78
South Atlantic									
1969	12	0.235	0.074	0.098	0.315	35.9 ± 5.9	37.1 ± 4.8	26.8 ± 3.2	n.a.
1970	36	0.168	0.068	0.069	0.358	47.2 ± 14.6	26.9 ± 13.3	26.1 ± 7.8	n.a.
1971	8	0.331	0.108	0.233	0.492	38.6 ± 9.7	41.9 ± 7.4	19.5 ± 11.8	1.62 ± 0.64
1973	3	0.117	0.052	0.076	0.175	45.3 ± 1.8	29.1 ± 7.1	25.7 ± 8.8	1.03 ± 0.55
1974	2	0.054	0.006	< 0.05	0.059	[1]59.3	[1]40.7	0 ± 0	[1]2.75
Florida									
1970	18	0.130	0.039	0.057	0.196	44.3 ± 11.8	16.1 ± 13.2	39.6 ± 7.1	[2]0.71 ± 0.01
Gulf of Mexico									
1969	2	0.102	0.006	0.097	0.106	32.4 ± 4.9	35.6 ± 2.2	32.6 ± 3.5	n.a.
1970	2	0.169	0.079	< 0.03	0.369	33.8 ± 9.8	33.1 ± 9.3	33.1 ± 8.7	n.a.
1972	4	0.164	0.126	0.088	0.353	34.3 ± 6.6	25.8 ± 10.5	40.2 ± 12.8	2.20 ± 0.68
1973	8	0.117	0.022	0.087	0.146	33.2 ± 6.2	37.8 ± 4.4	29.0 ± 5.9	1.42 ± 0.57
1974	9	0.059	0.038	0.028	0.155	33.2 ± 8.3	57.7 ± 10.6	9.2 ± 11.8	2.82 ± 0.98

When year omitted, either samples not obtained or analyses not performed.
n.a. = PCB not analyzed.
[1] One sample only.
[2] Two samples only.

Table 4.—ΣDDT in menhaden oil by area (1969-77).

Area and year	No. of samples	Mean (ppm)	SD	Low (ppm)	High (ppm)	Percent of ΣDDT as DDE	TDE	DDT	PCB/ΣDDT ratio
Middle Atlantic									
1969	6	5.93	1.78	4.42	9.36	37.5 ± 15.1	42.6 ± 10.1	19.8 ± 8.9	n.a
1971	2	4.99	0.283	4.79	[1]5.19	37.2 ± 5.4	44.7 ± 5.9	18.1 ± 0.6	2.36 ± 0.63
1972	5	4.40	1.06	2.73	5.49	43.6 ± 3.9	42.6 ± 3.7	13.9 ± 3.1	3.50 ± 0.19
1973	5	2.30	0.625	1.35	2.89	34.8 ± 13.2	43.3 ± 8.3	21.8 ± 9.2	2.62 ± 1.54
1974	4	1.11	0.332	0.743	1.54	34.7 ± 12.5	48.6 ± 7.5	16.6 ± 5.8	7.48 ± 4.19
1976	4	1.56	0.360	1.24	2.07	36.6 ± 10.1	52.0 ± 9.7	11.1 ± 1.2	5.56 ± 2.99
1977	6	0.978	0.207	0.745	1.21	28.8 ± 13.8	61.2 ± 12.6	10.0 ± 3.1	6.13 ± 1.84
Chesapeake Bay									
1969	2	3.41	0.834	2.82	4.00	19.0 ± 1.8	61.6 ± 7.3	19.2 ± 8.8	n.a.
1970	18	5.92	3.64	1.59	12.1	47.2 ± 17.0	33.0 ± 6.1	19.9 ± 13.2	n.a.
1972	4	3.78	0.519	3.01	4.16	40.2 ± 3.2	31.8 ± 3.4	27.9 ± 1.0	1.46 ± 0.30
1973	3	1.73	0.688	1.22	2.51	43.2 ± 8.5	36.8 ± 3.8	19.8 ± 6.0	1.57 ± 0.15
1974	5	1.02	0.136	0.902	1.24	38.7 ± 9.7	45.1 ± 4.0	16.3 ± 6.2	2.58 ± 0.47
1976	4	1.13	0.564	0.716	1.96	39.6 ± 15.3	48.8 ± 12.6	11.5 ± 3.1	1.59 ± 0.34
1977	4	0.708	0.355	0.380	1.21	54.4 ± 10.2	34.5 ± 9.1	11.2 ± 2.8	2.76 ± 0.59
South Atlantic									
1969	12	4.51	1.80	2.09	7.21	29.2 ± 4.2	43.9 ± 3.4	26.9 ± 2.0	n.a.
1970	29	3.93	1.20	2.47	7.14	41.0 ± 4.9	27.9 ± 4.2	31.1 ± 6.1	n.a.
1971	7	3.26	0.476	2.72	4.06	36.2 ± 4.3	41.6 ± 8.7	22.2 ± 7.0	1.18 ± 0.85
1973	3	1.34	0.263	1.04	1.51	34.6 ± 2.7	34.4 ± 2.8	30.6 ± 0.6	1.69 ± 0.45
1974	2	0.581	0.332	0.346	0.816	44.0 ± 5.4	46.2 ± 19.3	9.9 ± 13.9	2.73 ± 0.88
1976	6	0.819	0.339	0.496	1.44	42.3 ± 7.1	40.8 ± 4.0	17.0 ± 8.1	2.38 ± 1.82
1977	10	0.601	0.242	0.354	1.07	37.8 ± 10.3	49.1 ± 11.8	13.2 ± 4.6	2.70 ± 1.23
Gulf of Mexico									
1969	2	2.24	0.106	2.16	2.31	26.9 ± 6.6	36.8 ± 3.1	36.3 ± 3.7	n.a.
1970	42	2.55	1.05	<1.46	6.28	27.8 ± 6.6	44.1 ± 8.2	28.1 ± 8.3	n.a.
1972	4	1.94	0.677	1.39	2.89	28.8 ± 9.8	37.7 ± 9.7	33.5 ± 3.5	1.84 ± 0.61
1973	9	1.36	0.245	1.05	1.80	24.6 ± 5.2	39.7 ± 3.8	35.8 ± 4.7	0.96 ± 0.40
1974	9	0.992	0.348	0.557	1.71	23.3 ± 9.8	46.5 ± 6.5	30.3 ± 9.8	1.58 ± 0.91
1976	7	1.23	0.469	0.673	1.67	29.9 ± 5.0	48.2 ± 4.2	21.9 ± 7.6	0.94 ± 0.17
1977	16	0.838	0.304	0.290	1.38	37.2 ± 13.6	47.9 ± 15.5	14.9 ± 6.5	1.54 ± 0.40

When year omitted, either samples not obtained or analyses not performed.
n.a. = PCB not analyzed.
[1]North Carolina oil, January 1972 production, considered part of New Jersey fishery because of distinctly different chlorinated hydrocarbon characteristics from North Carolina early fall fishery.

Table 5.—ΣDDT in menhaden soluables and stickwater by area (1972-74).

Area and year	No. of samples	Mean (ppm)	SD	Low (ppm)	High (ppm)	Percent of ΣDDT as DDE	TDE	DDT	PCB/ΣDDT ratio
Middle Atlantic									
1972	5	0.368	0.140	0.234	0.580	55.0 ± 10.3	44.2 ± 9.7	0.9 ± 1.7	3.50 ± 0.80
1973	5	0.216	0.083	0.140	0.346	55.2 ± 12.3	41.3 ± 9.6	3.5 ± 3.4	3.10 ± 1.34
1974	4	0.125	0.064	0.069	0.182	50.5 ± 3.7	49.5 ± 3.7	0 ± 0	4.05 ± 0.62
Chesapeake Bay									
1972	4	0.212	0.068	0.130	0.297	46.0 ± 6.0	37.6 ± 9.5	16.4 ± 4.7	1.43 ± 0.43
1973	3	0.100	0.038	0.063	0.139	58.4 ± 1.2	41.6 ± 1.2	0 ± 0	2.53 ± 0.45
1974	5	0.053	0.018	0.033	0.070	54.8 ± 13.5	45.2 ± 13.5	0 ± 0	3.36 ± 1.62
South Atlantic									
1973	3	0.101	0.018	0.080	0.112	40.4 ± 3.7	42.1 ± 12.5	17.5 ± 13.2	1.67 ± 0.72
1974	2	0.022	0.005	0.019	0.026	51.3 ± 1.8	48.7 ± 1.8	0 ± 0	2.16 ± 0.59
Gulf of Mexico									
1972	1	0.232				46.6	53.4	0	1.55
1972	[1]3	0.038	0.022	<0.02	0.062	26.8 ± 12.2	44.2 ± 14.7	29.0 ± 2.3	14.55 ± 17.21
1973	9	0.150	0.070	0.0[2]	0.230	45.2 ± 9.7	51.8 ± 8.4	3.2 ± 7.0	1.71 ± 0.94
1974	8	0.092	0.024	0.039	0.123	38.1 ± 12.8	61.9 ± 12.8	0 ± 0	1.82 ± 1.06

When year omitted, either samples not obtained or analyses not performed.
[1] Stickwater; all other samples solubles.

Table 6.—PCB in menhaden fish by area (1969-76).

Area and year	No. of samples (total no. of fish)	Mean (ppm)	SD	Low (ppm)	High (ppm)
Middle Atlantic					
1969	1 (12)	6.59			
1971	1 (12)	3.25			
1972	5 (88)	3.67	1.54	1.58	5.7
1973	5 (81)	1.61	0.782	0.73	2.4
1974	4 (75)	1.05	0.390	0.61	1.5
1976	4 (73)	1.02	0.645	0.15	1.7
Chesapeake Bay					
1971	3 (28)	0.409	0.177	0.26	0.60
1974	3 (58)	0.271	0.169	0.17	0.46
1976	2 (31)	0.271	0.171	0.15	0.39
South Atlantic					
1971	6 (72)	0.510	0.313	0.14	0.94
1976	2 (36)	0.995	1.25	<0.11	1.88
Florida					
1970	1 (12)	0.454			
Gulf of Mexico					
1972	3 (42)	0.493	0.288	0.30	0.82
1973	8(155)	0.343	0.105	0.24	0.51
1974	9(184)	0.325	0.107	0.18	0.50
1976	6(139)	0.301	0.160	0.06	0.43

When year omitted, samples either not obtained or analyses not performed.

Table 7.—PCB in menhaden meal by area (1970-74).

Area and year	No. of samples	Mean (ppm)	SD	Low (ppm)	High (ppm)
Middle Atlantic					
1971	1	1.51			
1972	5	1.06	0.238	0.83	1.46
1973	5	0.518	0.274	0.18	0.91
1974	4	0.502	0.259	0.14	0.75
Chesapeake Bay					
1970	1	0.71			
1971	3	0.383	0.031	0.35	0.41
1972	4	0.447	0.010	0.44	0.46
1973	3	0.353	0.107	0.23	0.42
1974	5	0.242	0.074	0.19	0.37
South Atlantic					
1971	8	0.552	0.287	0.08	1.01
1973	3	0.116	0.066	0.05	0.18
1974	2	0.124	0.053	0.09	0.16
Florida					
1970	2	<0.1	0		
Gulf of Mexico					
1972	4	0.309	0.124	0.19	0.47
1973	8	0.172	0.087	0.06	0.34
1974	9	0.147	0.061	0.09	0.28

When year omitted, samples either not obtained or analyses not performed.

Table 8.—PCB in menhaden oil by area (1971-77).

Area and year	No. of samples (total no. of fish)	Mean (ppm)	SD	Low (ppm)	High (ppm)
Middle Atlantic					
1971	2	11.7	2.46	[1]9.9	13.4
1972	5	15.4	3.93	9.5	19.5
1973	5	6.2	3.53	1.4	9.9
1974	4	7.6	4.05	3.3	12.5
1976	5	8.0	3.54	3.6	12.0
1977	6	6.1	2.26	2.7	9.0
Chesapeake Bay					
1972	4	5.4	0.561	4.9	6.2
1973	3	2.7	0.856	1.9	3.6
1974	5	2.6	0.234	2.3	3.0
1976	5	1.8	0.596	1.2	2.6
1977	5	2.0	1.31	1.0	4.2
South Atlantic					
1971	7	3.6	2.23	1.3	7.0
1973	3	2.2	0.433	1.8	2.7
1974	2	1.7	1.42	0.73	2.7
1976	8	1.6	1.19	0.40	3.7
1977	10	1.9	1.64	0.59	5.8
Gulf of Mexico					
1972	4	3.3	0.561	2.7	4.0
1973	9	1.3	0.369	0.69	2.0
1974	9	1.5	0.888	0.90	3.6
1976	13	0.92	0.388	0.51	1.6
1977	18	1.22	0.302	0.50	1.6

When year omitted, samples either not obtained or analyses not performed.
[1] North Carolina oil, January 1972 production, considered part of New Jersey fishery because of distinctly different chlorinated hydrocarbon characteristics from North Carolina early fall fishery.

many of the components of PCB's than to the DDT family. Recognition and identification of those strange PCB peaks which appeared in the gas chromatograms used to quantify ΣDDT required complex analytical techniques, which are now used routinely in environmental studies, but which were just being developed in research laboratories during the late 1960's. Even today quantification of PCB's is a complex process, requiring much skill, experience, and attention to detail. Accurate and precise PCB analyses are still much more difficult to achieve than those for ΣDDT, dieldrin, or endrin.

In general, PCB levels decreased over the interval of this study, 1969-77, but the declines were less dramatic than for ΣDDT. The insecticide DDT was diluted substantially and sprayed thinly over wide areas. In this way it was readily absorbed on dust and soil particles, subjected to degradation by sunlight, air, and water, and buried by silt and sediment. When use stopped, the reservoir of ΣDDT generally disappeared rapidly. In contrast, in Alabama and California at two sites where DDT was manufactured and the wastes discharged without substantial dilution (O'Shea et al., 1980; Stout and Beezhold, 1981), large reservoirs of ΣDDT still remain and fauna collected nearby contained elevated levels of this contaminant long after manufacture of DDT ended. PCB's were most commonly used in large quantities in undiluted form as a dielectric fluid (insulator) in transformers and capacitors. Many old electrical systems are still in operation. Dispersal of PCB's from this equipment results from slow evaporation and spillage. More PCB's are slowly dissipating by seepage from equipment buried at waste-disposal sites. Thus, a huge reservoir of PCB's remains in the environment. It will take a long time to disappear. For example, in oil the mean for PCB's in the South Atlantic area went from 3.6 ppm in 1971 to 1.9 ppm in 1977, whereas for ΣDDT the value decreased from 3.26 ppm to 0.601 ppm during the same period. The PCB data are summarized in Tables 6-9.

Dieldrin and Endrin

The levels of dieldrin in the menhaden fishery have decreased over the years studied, as is most obvious from an examination of the high values for each set of data. For instance, in the South Atlantic fishery, the highest dieldrin level in 1969 was 1.53 ppm, compared with 0.16 ppm in 1977. The levels of dieldrin and endrin in menhaden fish and fishery products were always lower than those for ΣDDT and PCB's. One sample of oil collected in the Middle Atlantic area in 1969 contained 3.17 ppm dieldrin; another from the same area in 1972 contained 2.62 ppm. These were the exceptions. Even

Table 9.—PCB in menhaden solubles and stickwater by area (1972-74).

Area and year	No. of samples (total no. of fish)	Mean (ppm)	SD	Low (ppm)	High (ppm)
Middle Atlantic					
1972	5	1.29	0.527	0.58	1.8
1973	5	0.640	0.344	0.43	1.2
1974	4	0.513	0.289	0.23	0.85
Chesapeake Bay					
1972	4	0.285	0.068	0.22	0.38
1973	3	0.268	0.118	<0.13	0.36
1974	5	0.180	0.129	0.07	0.39
South Atlantic					
1973	3	0.160	0.036	0.13	0.20
1974	2	0.050	0.024	0.03	0.07
Gulf of Mexico					
1972	1	0.36			
1972	[1]3	0.362	0.281	<0.2	0.68
1973	9	0.246	0.183	0.08	0.68
1974	8	0.170	0.116	0.05	0.43

When year omitted, samples either not obtained or analyses not performed.
[1] Stickwater; all other samples solubles.

Table 10.—Dieldrin in menhaden fish and meal by area (1974-76).

Area and year	Type of sample	No. of samples[1]	Mean (ppm)	SD	Low (ppm)	High (ppm)
Middle Atlantic						
1974	Meal	4	0.015	0.006	0.007	0.021
1975	Meal	6	0.024	0.009	0.009	0.033
1976	Fish	5 (92)	0.066	0.010	0.058	0.080
Chesapeake Bay						
1974	Meal	5	0.011	0.003	0.006	0.013
1975	Meal	4	0.008	0.000	0.007	0.008
1976	Fish	5 (74)	0.017	0.005	0.013	0.023
South Atlantic						
1974	Meal	2	0.005	0		
1976	Fish	8(181)	0.010	0.004	0.003	0.015
Gulf of Mexico						
1974	Meal	9	0.029	0.014	0.008	0.059
1975	Meal	14	0.012	0.007	0.005	0.025
1976	Fish	12(249)	0.061	0.025	0.012	0.088

When year omitted, samples either not obtained or analyses not performed.
[1] Number in parentheses indicates total number of fish.

in the early years of the survey, fewer than 20 percent of the samples of menhaden oil contained more than 1 ppm dieldrin. Since the initial levels of

Table 11.—Dieldrin in menhaden oil by area (1969-77).

Area and year	No. of samples (total no. of fish)	Mean (ppm)	SD	Low (ppm)	High (ppm)
Middle Atlantic					
1969	6	0.91	1.11	0.37	3.17
1971	2	0.90	0.046	0.87	[1]0.94
1972	5	1.1	0.866	0.43	2.6
1973	5	0.51	0.207	0.24	0.78
1974	4	0.36	0.196	0.18	0.62
1975	6	0.36	0.149	0.17	0.58
1976	5	0.25	0.141	0.12	0.45
1977	6	0.20	0.109	0.11	0.41
Chesapeake Bay					
1969	2	0.54	0.081	0.48	0.60
1972	4	0.39	0.032	0.36	0.44
1973	3	0.31	0.008	0.30	0.31
1974	5	0.20	0.034	0.16	0.25
1975	5	0.20	0.046	0.15	0.28
1976	5	0.14	0.036	0.09	0.19
1977	5	0.11	0.043	0.07	0.16
South Atlantic					
1969	12	0.72	0.404	0.15	1.53
1971	7	0.40	0.163	0.26	0.67
1973	3	0.14	0.029	0.11	0.17
1974	2	0.09	0.025	0.07	0.11
1976	8	0.11	0.047	0.04	0.21
1977	10	0.08	0.048	0.03	0.16
Gulf of Mexico					
1969	2	0.46	0.257	0.28	0.64
1972	4	0.33	0.022	0.30	0.35
1973	9	0.42	0.149	0.18	0.56
1974	9	0.35	0.110	0.12	0.47
1975	14	0.31	0.139	0.12	0.54
1976	13	0.26	0.115	0.08	0.41
1977	18	0.11	0.077	0.01	0.24

When year omitted, samples either not obtained or analyses not performed.
[1] North Carolina oil, January 1972 production, considered part of New Jersey fishery because of distinctly different chlorinated hydrocarbon characteristics from North Carolina early fall fishery.

dieldrin and endrin in menhaden products were lower, the dramatic declines observed for ΣDDT and PCB's would not be anticipated. Our findings are summarized in Tables 10 and 11.

Endrin is an insecticide related to dieldrin, but with much more restricted usage, mainly in cotton production. Endrin levels were the lowest of all chlorinated hydrocarbons studied. The highest levels, e.g., 0.259 ppm in 1974, were found in menhaden oils from plants in the Gulf of Mexico area (Tables 12, 13).

Statistical Evaluations

The 719 data on chlorinated hydro-

Table 12.—Endrin in menhaden fish and meal by area (1974-76).

Area and year	Type of sample	No. of samples[1]	Mean (ppm)	SD	Low (ppm)	High (ppm)
Middle Atlantic						
1974	Meal	4	<0.01	0.008	0.003	<0.01
1975	Meal	6	<0.01	0		
1976	Fish	5 (92)	<0.009	0.002	0.005	<0.01
Chesapeake Bay						
1974	Meal	5	0.004	0.003	0.002	0.010
1975	Meal	4	0.01	0		
1976	Fish	5 (74)	0.002	0.001	0.001	0.004
South Atlantic						
1974	Meal	2	0.001	0.000	0.001	0.002
1976	Fish	8(181)	<0.005	0.004	0.001	<0.01
Gulf of Mexico						
1974	Meal	9	0.008	0.007	0.002	0.020
1975	Meal	14	0.006	0.004	0.001	0.009
1976	Fish	12(249)	0.012	0.005	0.004	0.020

When year omitted, samples either not obtained or analyses not performed.
[1] Number in parentheses indicates total number of fish.

carbons in menhaden oil provided the basis for statistical studies. Among the many possible questions, the most critical to answer were: "What happened to the levels of chlorinated hydrocarbons during the period studied?," and "Were the levels in the four areas of the menhaden fishery distinguishable?"

In the comparison for differences among years using the *F*-test, the null hypothesis of equality could be rejected for ΣDDT in all areas (Table 14), for PCB's except in the South Atlantic States (Table 15), and for dieldrin except in the Middle Atlantic States (Table 16). Where the null hypothesis was rejected, in order to identify differing groups, the data were further tested by Scheffe's method for multiple comparison (s-method), because this method can be applied when the sample sizes are not equal and more is known about the behavior of data (Scheffe, 1959). Examples of our findings follow. For ΣDDT in menhaden oils from the Middle Atlantic States, there were significant differences ($P<0.05$) between 1969 and 1973, 1974, 1976, or 1977,

Table 13.—Endrin in menhaden oil by area (1969-77).

Area and year	No. of samples	Mean (ppm)	SD	Low (ppm)	High (ppm)
Middle Atlantic					
1969	6	<0.04	0.004	<0.04	<0.05
1971	12	<0.03	0		
1972	5	0.028	0.004	0.021	0.031
1973	5	0.028	0.010	<0.02	0.045
1974	4	<0.05	0.007	0.036	<0.05
1975	6	0.021	0.005	0.016	0.031
1976	5	<0.023	0.005	<0.02	<0.03
1977	6	0.018	0.008	0.013	0.033
Chesapeake Bay					
1969	2	<0.05	0.014	<0.04	<0.06
1972	4	0.027	0.008	0.017	0.036
1973	3	0.040	0.029	0.023	0.074
1974	5	0.043	0.016	0.026	0.065
1975	5	0.023	0.009	0.013	0.032
1976	5	0.028	0.015	0.018	0.054
1977	5	0.016	0.006	0.010	0.025
South Atlantic					
1969	12	0.106	0.046	<0.05	0.197
1971	7	<0.031	0.002	<0.03	0.035
1973	3	<0.037	0.004	0.033	<0.04
1974	2	0.028	0.005	0.025	0.032
1976	8	0.025	0.010	0.012	0.040
1977	10	0.015	0.005	0.009	0.027
Gulf of Mexico					
1969	2	0.100	0.071	<0.05	0.150
1972	4	0.064	0.006	0.058	0.071
1973	9	0.076	0.032	<0.03	0.121
1974	9	0.097	0.078	0.028	0.259
1975	14	0.074	0.037	0.017	0.147
1976	12	0.059	0.023	0.028	0.095
1977	18	0.049	0.041	<0.01	0.127

When year omitted, samples either not obtained or analyses not performed.
[1] North Carolina oil, January 1972 production, considered part of New Jersey fishery because of distinctly different chlorinated hydrocarbon characteristics from North Carolina early fall fishery.

between 1971 and 1974, 1976, or 1977, and between 1972 and 1974, 1976, or 1977. There were differences in PCB levels in both the Chesapeake Bay and Gulf of Mexico areas between 1972 and 1973, 1974, 1976, and 1977. For menhaden oils collected from plants in Chesapeake Bay significant differences in dieldrin levels existed between 1969 and 1972, 1973, 1974, 1975, 1976, or 1977, between 1972 and 1974, 1975, 1976, or 1977, and between 1973 and 1976 or 1977. The details are shown in Table 17.

Comparison of data for differences among areas within a single year showed that ΣDDT in menhaden oils differed significantly ($P < 0.05$) in the years 1970 through 1973, but not in 1969 or 1974 through 1977. During all the years that PCB's were analyzed, samples of oils from the Middle Atlantic States differed from those from other areas. In 5 of 8 years, namely 1971, 1973, 1974, 1976, and 1977, dieldrin levels differed among areas. In 1971, 1973, and 1977, dieldrin levels in the Middle Atlantic area differed from those in the South Atlantic area. In 1973 the dieldrin level in the South Atlantic area also differed from that in the Gulf of Mexico area, and in 1976 the only difference was be-

Table 14.—Analysis of variance (ANOVA) tables for ΣDDT in menhaden oil among years within specific areas.

Source and area	Sample size	df	Sum of squares	Mean square	F-value
Middle Atlantic					
Years	7	6	118.911	19.818	21.701*
Within		25	22.832	0.913	
Total	32	31	141.742	4.572	
Chesapeake Bay					
Years	7	6	198.826	33.138	4.775*
Within		33	228.992	6.939	
Total	40	39	427.818	10.970	
South Atlantic					
Years	7	6	158.897	26.483	20.883*
Within		62	78.627	1.268	
Total	69	68	237.524	3.493	
Gulf of Mexico					
Years	7	6	48.924	8.154	13.201*
Within		82	50.651	0.618	
Total	89	88	99.574	1.132	

*$P < 0.05$.

Table 15.—ANOVA tables for PCB in menhaden oil among years within specific areas.

Source and area	Sample size	df	Sum of squares	Mean square	F-value
Middle Atlantic					
Years	6	5	323.960	64.792	5.615*
Within		21	242.308	11.538	
Total	27	26	566.268	21.780	
Chesapeake Bay					
Years	5	4	35.856	8.964	14.016*
Within		17	10.872	0.640	
Total	22	21	46.728	2.225	
South Atlantic					
Years	5	4	18.627	4.657	1.755*
Within		25	66.345	2.654	
Total	30	29	84.972	2.930	
Gulf of Mexico					
Years	5	4	18.015	4.504	18.459*
Within		48	11.711	0.244	
Total	53	52	29.726	0.572	

*$P < 0.05$.

Table 16.—ANOVA tables for dieldrin in menhaden oil among years within specific areas.

Source and area	Sample size	df	Sum of squares	Mean square	F-value
Middle Atlantic					
Years	8	7	4.272	0.610	1.953
Within		31	9.686	0.312	
Total	39	38	13.958	0.367	
Chesapeake Bay					
Years	7	6	0.437	0.073	45.364*
Within		22	0.035	0.002	
Total	29	28	0.473	0.017	
South Atlantic					
Years	6	5	3.114	0.623	11.263*
Within		36	1.991	0.055	
Total	42	41	5.105	0.125	
Gulf of Mexico					
Years	7	6	0.859	0.143	10.392*
Within		62	0.854	0.014	
Total	69	68	1.714	0.025	

*$P < 0.05$.

Table 17.—Test (*F*-test) of null hypothesis for differences in chlorinated hydrocarbon levels among years in menhaden oil collected from plants in four areas.

Area and year	Test of null hypothesis		
	ΣDDT	PCB	Dieldrin
Middle Atlantic			
1969	de	n.a.	n
1971	df	d	n
1972	dg	de	n
1973	de′	de′	n
1974	de′f′g′	d	n
1975	n.a.	n.a.	n
1976	de′f′g′	d	n
1977	de′f′g′	de′	n
Chesapeake Bay			
1969	ds	n.a.	de
1970	ds	n.a.	n.a.
1972	ds	de	de′f
1973	ds	de′	de′g
1974	ds	de′	de′f′
1975	n.a.	n.a.	de′f′
1976	ds	de′	de′f′g′
1977	ds	de′	de′f′g′
South Atlantic			
1969	de	n.a.	de
1970	df	n.a.	n.a.
1971	dg	n	d
1973	de′f′	n	de′
1974	de′f′	n	d
1976	de′f′g′	n	de′
1977	de′f′g′	n	de′
Gulf of Mexico			
1969	d	n.a.	de
1970	de	n.a.	n.a.
1972	d	de	d
1973	de′	de′	de
1974	de′	de′	de
1975	n.a.	n.a.	de
1976	de′	de′	d
1977	de′	de′	de′

When year omitted, samples either not obtained or analyses not performed.

n Cannot reject the null hypothesis of no difference among years (*F*-test), within a single area.

n.a. Not analyzed.

d Reject the null hypothesis of no difference among years, within a single area.

e Years marked "e" differ from years marked "e′", within a single area.

f Years marked "f" differ from years marked "f′", within a single area.

g Years marked "g" differ from years marked "g′", within a single area.

s Although the *F*-test rejected the hypothesis of equality of means for the Scheffe multiple comparison procedure, no confidence intervals for mean differences failed to contain the point zero.

Table 18.—ANOVA tables for ΣDDT in menhaden oil among areas for a specific year.

Source and area	Sample size	df	Sum of squares	Mean square	*F*-value
1969					
Areas	4	3	24.761	8.254	2.861
Within		18	51.936	2.885	
Total	22	21	76.696	3.652	
1970					
Areas	3	2	145.618	72.809	20.152*
Within		86	310.719	3.613	
Total	89	88	456.337	5.186	
1971					
Areas	2	1	4.679	4.679	22.760*
Within		7	1.439	0.206	
Total	9	8	6.118	0.765	
1972					
Areas	3	2	13.983	6.991	10.505*
Within		10	6.655	0.666	
Total	13	12	20.638	1.720	
1973					
Areas	4	3	3.152	1.051	5.380*
Within		16	3.125	0.195	
Total	20	19	6.277	0.330	
1974					
Areas	4	3	0.393	0.131	1.415
Within		16	1.483	0.093	
Total	20	19	1.876	0.099	
1976					
Areas	4	3	1.363	0.454	2.386
Within		17	3.238	0.190	
Total	21	20	4.601	0.230	
1977					
Areas	4	3	0.630	0.210	2.680
Within		32	2.507	0.078	
Total	36	35	3.137	0.090	

*$P < 0.05$.

Table 19.—ANOVA tables for PCB in menhaden oil among areas for a specific year.

Source and area	Sample size	df	Sum of squares	Mean square	*F*-value
1971					
Areas	2	1	100.018	100.018	19.543*
Within		7	35.825	5.118	
Total	9	8	135.844	16.980	
1972					
Areas	3	2	385.654	192.827	30.265*
Within		10	63.713	6.371	
Total	13	12	449.367	37.447	
1973					
Areas	4	3	79.095	26.365	8.015*
Within		16	52.634	3.290	
Total	20	19	131.729	6.933	
1974					
Areas	4	3	108.790	36.263	10.066*
Within		16	57.639	3.602	
Total	20	19	166.430	8.759	
1976					
Areas	4	3	190.459	63.486	27.105*
Within		27	63.240	2.342	
Total	31	30	253.699	8.457	
1977					
Areas	4	3	108.006	36.002	21.656*
Within		35	58.185	1.662	
Total	39	38	166.191	4.373	

*$P < 0.05$.

tween those two areas. The details of the interarea comparisons are shown in Tables 18-21.

Examination of Tables 17 and 21 shows two instances in which the null hypothesis was rejected, but no groups differed. In the case of ΣDDT in menhaden oils collected from plants in the Chesapeake Bay area, although the *F*-test rejected the hypothesis of equality of means among years, for the Scheffe (1959) multiple comparison procedure, no confidence intervals for mean differences failed to contain the point zero (Table 17). This behavior of data is uncommon, but occurred in the test between areas for 1974 dieldrin data as well (Table 21).

Interpretation of Results

The levels of chlorinated hydrocarbons decreased in most types of samples during the period studied, but statistical analyses did not always confirm this observation. Several factors contributed to this discrepancy: 1) The number of samples of a specific type from a single area was sometimes extremely limited; 2) the number of samples varied widely from year to year; 3) marine fish from even a single catch vary widely in chlorinated hydrocarbon content (Stout and Beezhold, 1981); 4) the size and age distribution of menhaden catches fluctuated broadly, in response to conditions in the fishery; 5) Atlantic menhaden migrate a long distance, north in the spring and south in the fall (Dryfoos et al., 1973); 6) in later years, especially in the Atlantic fishery, fish contained exceptionally small amounts of oil; and 7) with the introduction of refrigeration, fishing vessels extended their range, so that previously discrete fishing areas lost some definition.

To explain in more detail, we collected a total of 268 samples of menhaden oil during the 9 years of the survey, but some years we collected no samples from a specific area because no fish appeared there. When fishing did occur, some years we received only two samples from an area. At the other extreme, in 1970 we collected more than 40 samples each of meal and oil from the Gulf of Mexico (Tables 3, 4). Furthermore, sometimes the fish were small, other times

Table 20.—ANOVA tables for dieldrin in menhaden oil among areas for a specific year.

Source and area	Sample size	df	Sum of squares	Mean square	*F*-value
1969					
Areas	4	3	0.417	0.139	0.312
Within		18	8.011	0.445	
Total	22	21	8.427	0.401	
1971					
Areas	2	1	0.392	0.392	16.966*
Within		7	0.162	0.023	
Total	9	8	0.554	0.069	
1972					
Areas	3	2	1.842	0.921	3.065
Within		10	3.006	0.301	
Total	13	12	4.848	0.404	
1973					
Areas	4	3	0.292	0.097	4.433*
Within		16	0.351	0.022	
Total	20	19	0.644	0.034	
1974					
Areas	4	3	0.168	0.056	4.121*
Within		16	0.218	0.014	
Total	20	19	0.386	0.020	
1975					
Areas	3	2	0.072	0.036	2.153
Within		22	0.370	0.017	
Total	25	24	0.443	0.018	
1976					
Areas	4	3	0.130	0.043	4.494*
Within		27	0.260	0.010	
Total	31	30	0.390	0.013	
1977					
Areas	4	3	0.065	0.022	4.030*
Within		35	0.188	0.005	
Total	39	38	0.253	0.007	

*$P < 0.05$.

Table 21.—Test (*F*-test) of null hypothesis for differences in chlorinated hydrocarbon levels menhaden oils among areas.

Chlorinated hydrocarbon and year	Area			
	Middle Atlantic	Chesapeake Bay	South Atlantic	Gulf of Mexico
ΣDDT				
1969	n	n	n	n
1970	n.a.	de	de'f	de'f'
1971	de	n.a.	de'	n.a.
1972	de	df	n.a.	de'f'
1973	de	d	d	de'
1974	n	n	n	n
1976	n	n	n	n
1977	n	n	n	n
Polychlorinated biphenyls				
1971	de	n.a.	de'	n.a.
1972	de	de'	n.a.	de'
1973	de	d	d	de'
1974	de	de'	de'	de'
1976	de	de'	de'	de'
1977	de	de'	de'	de'
Dieldrin				
1969	n	n	n	n
1971	de	n.a.	de'	n.a.
1972	n	n	n	n
1973	de	d	de'f	df'
1974	ds	ds	ds	ds
1975	n	n	n	n
1976	d	d	de	de'
1977	de	d	de'	d

When year omitted, samples either not obtained or analyses not performed.

n Cannot reject the null hypothesis of no difference among areas (*F*-test), within a single year.

n.a. Not analyzed.

d Reject the null hypothesis of no difference among areas, within a single year.

e Areas marked "e" differ from areas marked "e'", within a single year.

f Areas marked "f" differ from areas marked "f'", within a single year.

s Although the *F*-test rejected the hypothesis of equality of means for the Scheffe multiple comparison procedure, no confidence intervals for mean differences failed to contain the point zero.

they were very large. These were the normal fluctuations in the menhaden fishery. When fish were scarce, smaller fish, more commonly allowed to mature further, were taken for reduction. The chlorinated hydrocarbon content of samples was dependent on the age structure of the catches. Menhaden live in different environments at different stages of development. In the spring, maturing Atlantic menhaden, which constitute one single population (Dryfoos et al., 1973) migrate northward from an unknown wintering area offshore in the Atlantic. The youngest fish apparently spawn farthest south, in Florida, North Carolina, and Chesapeake Bay. Older fish travel as far as New Jersey, New York, and in some years even Massachusetts and Maine before spawning. Menhaden spawn just on the edge of the shore and the eggs drift into estuaries to develop. Juvenile menhaden spend many months in the estuaries before migrating southward in the fall along with the older fish from farther north. Larger fish often contain higher concentrations of chlorinated hydrocarbons, whether because of longer exposure, greater pollution in more northerly waters or other factors is not known. When taken on their first southward migration, juvenile fish coming from highly polluted estuaries presumably also contain higher levels of contaminants than their surviving cohorts after wintering over in the cleaner environment of the open sea.

Unrelated to size and migration, the concentration of chlorinated hydrocarbons in the oil of a fish depends directly on the oil content of the animal. In other words, independent of the absolute amount of contaminant (total micrograms) present, the more oil in the fish the lower the concentration of chlorinated hydrocarbons (i.e., micrograms per gram oil). Once deposited in fish, these contaminants tend to remain there for life. The chlorinated hydrocarbons are very soluble in oil and nearly insoluble in water and proteins. In live animals these containants are associated with the fatty tissue. During reduction they concentrate in the oil and the oil remaining in the meal, stickwater, and solubles. Contrary to possible expectations, the oil content of menhaden varies markedly from year to year.

In the mid-1970's, for unknown reasons, Atlantic menhaden contained extremely small amounts of oil. The levels of chlorinated hydrocarbons in menhaden products, therefore, may have been deceptive. Anticipated decreases with restriction in use of chlorinated hydrocarbons may have been masked by the marked decrease in menhaden oil in this marine resource. More extensive sampling of fish would have eliminated most of these problems, but because of difficulties in handling fresh fish, they were not always collected. In spite of all these complexities in the sampling, both the means and the high values did decrease regularly in most types of samples from most areas, indicating that the amounts of chlorinated hydrocarbons to which menhaden were exposed were decreasing at least to a limited extent.

Conclusions

We monitored the levels of chlorinated hydrocarbons throughout the menhaden fisheries in both the Atlantic Ocean and the Gulf of Mexico from 1969, when DDT was still common, until 1977, when DDT had been banned and PCB's drastically curtailed. DDT and its metabolites

TDE and DDE, PCB's as well as dieldrin and endrin, were found in most samples of whole menhaden and the reduction products, meal, oil, solubles, and stickwater, from all areas of the fisheries. The very high levels found in the earlier years (a maximum of 12 ppm Σ DDT, 20 ppm PCB's and 3 ppm dieldrin in menhaden oil) declined sharply with increasing restriction in usage of chlorinated hydrocarbons. By 1977 the highest levels in the oil were 1.4 ppm ΣDDT, 9 ppm PCB's, and 0.4 ppm dieldrin. In 1977 the highest means, 1.0 ppm ΣDDT, 6 ppm PCB's, and 0.2 ppm dieldrin, occurred in the Middle Atlantic fishery. This fishery represents a very small proportion of the total catch. The mean levels of PCB's and dieldrin in the other three areas were much lower. Since the Middle Atlantic fishery involves the largest proportion of older fish, with time the levels in this area may drop as well. Both the means and the high values for chlorinated hydrocarbons decreased in most types of samples from most areas during the period of this study. Nonetheless statistical analyses, using the *F*-test and Scheffe's (1959) method for multiple comparison (s-method) on 541 data for menhaden oil, only partially confirmed these findings. Possible reasons for these observations include, among others, limitation and variation in sample size, variability of chlorinated hydrocarbon level in fish from a single catch, and the broad migration of menhaden, at least in the Atlantic fishery.

Over the years studied following the restriction in use of DDT, the proportion of ΣDDT present in samples as DDT itself decreased. The anaerobic metabolite of DDT that forms in the marine environment, TDE, increased during the same interval. The proportions of DDT, TDE, and DDE were generally similar in all types of samples except meal, which contained a greater proportion of DDE. Degradation of DDT to DDE, which commonly occurs on land and in the freshwater environment, may be accelerated at the elevated temperatures of the meal drier.

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Acylation of Fish Protein: Effect of Reaction Conditions on Products

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Introduction

Functionality is the attribute of a food material that gives the desired properties to the food system in which it has been incorporated. For example, it is the emulsion-stabilizing functionality of egg yolk that makes possible the fat-in-water emulsion that is the basis of mayonnaise. It has been shown that the functional properties of fish muscle proteins can be improved by chemically modifying these proteins (Groninger and Miller, 1975; Miller and Groninger, 1976). Modification through the acylation of fish myofibrillar protein has been described by Groninger (1973) and Chen et al. (1975). Acylation involves the chemical bonding of a small molecule, in most instances acetyl or succinyl, to the protein which results in an alteration of the electrical charge on the protein.

Recent studies of the chemical and nutritional properties of acylated fish protein (Groninger and Miller, 1979) included determination of their nutrititive value and biological utilization relative to acylation reaction conditions. Rat feeding tests showed clearly that acylation resulted in decreased nutritional value of the modified protein as measured by the protein efficiency ratio and the feed efficiency. A modified protein with improved functional properties and reasonably good nutritional value was produced, however, at low to moderate levels of acylation. Such a product would be desirable for food applications in which the modified protein additives might be a significant part of the protein intake. Therefore commercial applications of the process will require selection and control of reaction conditions to provide modified protein with the needed functional properties as well as reasonably good nutritive value. For this purpose, detailed knowledge of acylation reaction conditions and the effects on products is important.

Although the major target of the acylation reaction is the amino group of the amino acid lysine (Grant-Green and Friedberg, 1970), minor reactions occur to form secondary products with cysteine (Habeeb et al., 1958), tyrosine (Riordan and Vallee, 1963), and with serine and/or threonine (Gounaris and Perlmann, 1967). In most reported work on the acylation of proteins for food purposes, little attention has been given to the formation of these secondary products. Since these secondary products may be important from the point of view of nutrition, food safety, and the functionality of the modified protein, work on secondary products was initiated.

The objective of this work was to determine the relative reactivity of the various sites on the fish protein that might involve the acylation reagent; this includes the epsilon-amino group of lysine, the sulfhydryl group of cysteine, the phenolic group of tyrosine, and the hydroxyl groups of serine and threonine when fish myofibrillar protein is acylated under various conditions. The inhibitory effect of sulfite on the acylation reaction was also evaluated.

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Methods

The various methods used in this work are described as follows.

Preparation of Myofibrillar Proteins

The procedure for the preparation of myofibrillar proteins was based on the method described by Groninger (1973). Fresh or defrosted rockfish (*Sebastes* spp.) fillets were comminuted by passing through a food grinder with a 0.2 cm orifice plate. The comminuted fish muscle was suspended three times in a large excess volume of cold 0.1 *M* NaCl to remove a large proportion of water-soluble proteins, minerals, and other extractives. The supernatant was removed by centrifugation for 10 minutes at 8,000 *g*, 0°C. To remove additional soluble protein, the muscle protein was blended for 20 seconds in a high-speed blender with about 3 volumes of 0.1 *M* NaCl at 0°C and centrifuged for 10 minutes at 8,000 *g*, 0°C. Blending and subsequent centrifugation was also repeated three times. The myofibrillar proteins were solubilized by blending for 30 seconds in 0.6 *M* NaCl at 0°C. Connective tissue and nonsolubilized myofibrillar protein were removed by centrifugation for 15 minutes at 13,000 *g*, 0°C. The typical protein preparation contained 30 to 32 mg protein/g.

Acylation of Fish Protein

Salt-solubilized myofibrillar protein, at a concentration of approximately 30 mg/g, was acetylated by reacting with acetic anhydride under a constant agitation in an ice bath at different pH's and with or without the addition of sodium sulfite. Acetic anhydride was added dropwise by a microburette in a constant rate of addition (0.5 g/minute). Simultaneous-

ly, 2 *N* NaOH was added to provide a pH stat-like condition during the reaction period, which normally took 40-60 minutes in a 600 ml of total reaction volume.

Succinylation was carried out using a procedure similar to the acetylation procedure except that incremental amounts of solid succinic anhydride were added.

Protein Content

Protein content was determined by the method of Lowry et al. (1951).

Extent of Acylation

The extent of acylation of protein was measured by the method of Kakade and Liener (1969) and calculated as percent acylation based on the amounts of free amino groups in the acylated and the native samples.

Acylhydroxamates

To estimate the amount of acylated secondary side groups in protein, acylhydroxamates were determined by Hestrin's method (1949). Acylhydroxamates are formed by deacetylation of acylated residues with alkaline hydroxylamine and subsequently the ferric acylhydroxamate complex is formed which has an absorption maximum of 540 mm.

In the preliminary work with acetylated compounds, it was found that deacetylation with hydroxylamine occurred selectively on protein residues under conditions of controlled pH. As shown in Table 1, all of the acetyl compounds were readily deacetylated at pH 12.5 while S-mixture and O-acetyltyrosine were reacted at pH 7.5, although the recovery was slightly reduced. O-acetyltyrosyl derivatives were readily deacetylated when acetylated proteins were tested as described by Riordan and Vallee (1972). Furthermore, an estimation of cysteine could be made in the presence of O-acetyltyrosine when deacylation was performed at pH 6.5 to 6.0. However, this was not satisfactory for a quantitative test because of variability.

Therefore, the deacylation values measured at pH 12.5 are the total amount of acyl groups on secondary residues including tyrosyl, sulfhydryl, and hydroxyl; and the values measured at pH 7.5 are the sum of tyrosyl and sulfhydryl residues. The deacylation values measured at pH 7.5 were very similar to those values of O-acyl tyrosine and S-acyl cysteine, which were measured individually by the methods of Riordan et al. (1965) and Habeeb (1972). The amounts of acylated O-hydroxyl residues as the total of O-serine and O-threonine were simply computed by subtracting the amount of O-acyl tyrosine plus S-acyl cysteine from the total deacylation value measured at pH 12.5.

Percent acylation given in the data was calculated as the percent ratio of each secondary residue in mg/100 g protein based on the contents of corresponding amino acids from the data of amino acid composition of rockfish protein by Groninger and Miller (1979).

The hydroxylamine deacylation reagent consisted of 10 ml of 2 *M* NH_2OH and 10 ml of 3.5 *N* NaOH for the test at pH 12.5; a mixture of 10 ml 2 *M* NH_2OH and an appropriate amount of 3.5 *N* NaOH for the test at pH 7.5. In general procedure for deacylation, 2 ml of 1 *M* hydroxylamine reagent was added to 1.0 ml aliquots of protein solution and reacted for 10 minutes at room temperature. The reaction was stopped by addition of 1.0 ml of concentrated HCl diluted at 1:2 (v/v) and subsequently 1.0 ml of 1 percent ferric chloride in 0.1 *N* HCl was added. The protein precipitate formed was removed by filtration, and the absorbance of the supernatant was measured by 540 nm 20 minutes after the addition of ferric chloride. Quantitation in all cases was based on standard curves using acetylcholine and monomethylsuccinate.

Table 1.—Deacetylation recovery of O- and S-acetyl compounds with hydroxylamine at pH 12.5 and 7.5.

Test mixture	Concentration (m*M*)	Recovery at pH 12.5 (m*M*)	12.5 %	Recovery at pH 7.5 (m*M*)	7.5 %
O-mixture 1 m*M* O-acetylhydroxyproline 0.25 m*M* O-acetyltyrosine 1 m*M* N,O-diacetylserine	2.25	2.21	98	0.25	11
S-mixture 1 m*M* S-acetylthiocholine 1 m*M* S-acetylmercaptosuccinate 1 m*M* N,S-diacetylcysteine	3.00	3.05	102	2.78	93
O- and S-mixture Same amount of O- and S-mixture	2.63	2.55	97	1.41	54

Analysis of O-acyl Tyrosine

A spectral determination method for tyrosine was adapted to estimate acyl O-tyrosine after deacylation with hydroxylamine. This test is based on the shift of absorption maximum from 263 to 278 nm and an increase in molar absorptivity when O-tyrosine residues of protein are deacylated.

In practice, solubilized fish myofibrillar protein was found to be too turbid for direct spectrophotometric analysis without clarification by proteolytic treatment prior to deacylation. This was accomplished by incubating 10 ml of solubilized protein suspension in barbital buffer (pH 7.5) with 1 ml of trypsin-bromelain mixture (50 + 100 mg/40 ml H_2O for 30 to 60 minutes at room temperature. If necessary, the protein solution was incubated for an additional 60 minutes at 30°C in a shaker bath. The mixture was clarified by centrifugation for 15 minutes at 18,000 *g*, 0°C. Deacylation of O-acyl tyrosine in 1.0 ml of enzyme-treated protein solution was accomplished with 2 ml of 1 *M* hydroxylamine reagent (pH 7.5) for 10 minutes at room temperature. The volume was adjusted to 5 ml with water, and the absorbance was measured at 278 nm. The increase in absorbance at 278 nm between the native and acylated proteins, E_{278} = 1,100 per mole, was used to determine the amount of O-acyl tyrosine in acylated fish protein.

Analysis of S-acyl Cysteine

Sulfhydryl was estimated using

Ellman's reagent and the general procedure of Habeeb (1972); however, it was adapted for use on modified fish protein. In this modified procedure, acylated sulfhydryl groups were deacylated with hydroxylamine prior to reaction with Ellman's reagent, and the difference in absorbance at 412 nm between the control and modified protein was measured. A result of the quantitive determination of N,S-diacetylcysteine through the reaction with 5,5-dithiobis-(nitrobenzoic acid) (DTNB) reagent is shown in Table 2. At least 2 ml of 1 *M* hydroxylamine for deacetylation and 1.0 ml of 2 m*M* DTNB reagent were required to develop a quantitive color reaction. The concentration of the sample was shown to be a critical factor, and the absorbance of the range of 0.4-0.7 was used for best recovery.

For deacylation, 1 ml of 2 percent sodium dodecyl sulfate phosphate buffer solution (pH 8.0) with 0.2 ml of 0.2 *M* EDTA and 2 ml of 1 *M* hydroxylamine (pH 7.5) were added to 1 ml of enzyme-treated protein solution. After deacylating for 10 minutes at ambient temperature, 1 ml of 2 m*M* DTNB was added, the volume was made up to 5 ml with water, and the absorbance was measured at 412 nm. A molar absorptivity of 13,000 was used for the calculation of the amount of S-acyl sulfhydryl. Because hydroxylamine appeared to cause fading of the color, the absorbance was read within several seconds after the addition of the DTNB reagent.

Table 2.—Recovery and optimum reaction conditions for deacylation of N,S-diacetylcysteine and subsequent quantitation with 5,5′-dithiobis-(2-nitrobenzoic acid).

N,S-diacetyl-cysteine (0.2 m*M*) (ml)	Deacylation with 1 *M* hydroxylamine (ml)	2 m*M* DTNB reagent (ml)	Recovery (percent)
1.0	2.0	1.0	99
1.0	2.0	0.5	55
1.0	2.0	0.2	38
1.0	1.0	1.0	48
1.0	1.0	0.5	34
1.0	1.0	0.2	27

Results

For the purpose of simplification, the results are presented in the following six sections.

Acetylation of Amino Group

Salt-solubilized fish myofibrillar proteins were acetylated with acetic anhydride at three different pH's (9.5, 7.5, and 6.5), and at various levels of acetylating agent at 0°C. The extent of acetylation was expressed in terms of percentage of reactive lysine residues with 2,4,6-trinitrobenzenesulfonic acid reagent. As shown in Figure 1, the rate of reaction was affected by both pH and concentration of reagent. The reaction proceeded much faster at pH 9.5 than at lower pH's. The reaction was almost complete even under relatively mild conditions with 30 to 50 m*M* anhydride (ratio to protein, 1:8 to 1:5) at each pH until the proteins were 80-90 percent acetylated. At 40 m*M* anhydride concentration, acetylation was about 90 percent complete at pH 9.5, whereas only 75 and 65 percent were complete at pH 7.5 and 6.5, respectively. This shows that different amounts of anhydride were required to provide the same degree of acetylation at different pH's. For example, approximately 30, 45, and 55 m*M* of anhydride were added to yield 80 percent acetylation at pH 9.5, 7.5, and 6.5, respectively. With amounts of acetic anhydride in excess of 80 m*M* (ratio to protein, 1:4), the reaction was completed rapidly, leading to over 90 percent acetylation at each pH.

The effect of the rate of anhydride addition was evaluated; however, significant differences in overall reaction rates were not observed when 0.5 to 1.0 g/minute anhydride was added. In all other experimental work, acylating agents were added in the rate of 0.5 g/minute.

Acetylation of Secondary Groups

The relative reactivities of secondary groups are shown in Figures 2 to 5. The general features of the acetylation of total secondary groups were

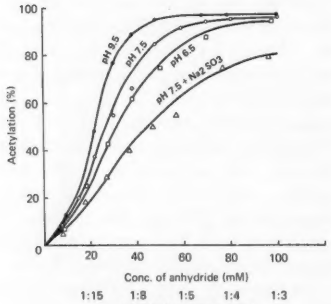

Figure 1.—The reactivity of amino groups of fish myofibrillar protein during acetylation with acetic anhydride (protein content, 30.2-31.6 mg/g).

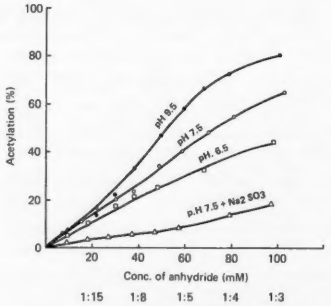

Figure 2.—Overall reactivity of the total secondary groups of fish myofibrillar protein with acetic anhydride (protein content, 30.2-31.6 mg/g).

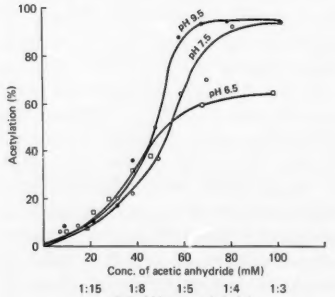

Figure 3.—The reactivity of tyrosyl group of fish myofibrillar protein with acetic anhydride (protein content, 30.2-31.6 mg/g).

similar to the acetylation of the amino group, except that the reaction rate was greatly reduced at lower pH's (Fig. 2). For example, at 40 m*M* anhydride, about 35, 25, and 20 percent of total secondary groups were reacted at pH 9.5, 7.5, and 6.5, respectively, while at least 65 to 90 percent of the amino groups were acylated at the same anhydride concentration.

The rates of acetylation of secondary groups at pH 6.5 and 7.5 appeared to be relatively linear; however, at pH 9.5, concentration of acetic anhydride between 40 to 70 m*M* increased the rate considerably. When Figures 1 and 2 are considered, it can be seen that total acylation at secondary residues of protein might be kept relatively low by controlled use of anhydride and somewhat minimized by acetylating at pH 9.5. On the other hand, relatively high levels of acetylation of the secondary groups can only be accomplished after the acetylation of the amino group is almost complete.

Acetylation of Tyrosyl Group

As shown in Figure 3, the phenolic group of tyrosine can be acetylated to a level of more than 90 percent by using a high concentration of anhydride and extended reaction time. The reactivity of the tyrosyl group was relatively low at lower levels of reagent. For example, at 40 m*M* anhydride concentration, approximately 30 percent of tyrosyl groups were reacted; and at above 50 m*M* of anhydride at pH 6.5, the reaction rate decreased considerably. Again, it is noticeable that the rate of the reaction tended to accelerate dramatically at pH 9.5 and 7.5 with 40 to 60 m*M* anhydride, at which point the acetylation of amino groups was nearly complete. This tendency was revealed more clearly on tyrosyl groups than in the overall reaction of total secondary groups because the acylation of tyrosyl groups is quantitatively much greater than acylation of sulfhydryl and hydroxyl groups, particularly at higher concentration of anhydride. The pH dependence of the reaction was not as great between pH 7.5 and 9.5 as between pH 7.5 and 6.5, and this effect was more evident at higher concentrations of anhydride than at lower levels.

Acetylation of Sulfhydryl Group

Unlike tyrosyl or hydroxyl residues, the sulfhydryl group of fish protein showed a high reactivity with acetic anhydride even at lower levels of anhydride concentration, yielding over 50 percent acetylation with 40 m*M* anhydride (ratio to protein, 1:8) at both pH 9.5 and 7.5 (Fig. 4). The pattern of the reaction was also different from those of the other residues in that the overall reaction proceeded similarly to the amino group reaction. The reaction rate of pH 6.5 was significantly less than at pH 7.5 and 9.5 with anhydride levels greater than 30 m*M* (ratio to protein, 1:10). A relatively high acylation reactivity of sulfhydryl in papain compared with more simple compounds has been reported by Finkle and Smith (1958), Wallenfels and Eisele (1968), and Chaiken and Smith (1969a). Chaiken and Smith (1969b) suggested that an explanation for the high rate of reaction of the sulfhydryl group with some acylating agents may be intraprotein interactions involving the sulfhydryl, imidazolium, and carboxylate groups of the protein which may cause increased nucleophility of the sulfur anion.

Acylation of Hydroxyl Group

It has been generally known that the hydroxyl groups of serine and threonine show the lowest reactivity with acetic anhydride compared with other secondary side groups. The reaction rates at pH 6.5 and 7.5 decrease at about 30 m*M* anhydride and lower concentrations and increase at high levels of anhydride concentration. The reaction rate at pH 9.5 is relatively linear up to 100 m*M* anhydride. No more than 28 percent was modified with 40 m*M* anhydride at pH 9.5 (Fig. 5).

Inhibitory Effect of Sodium Sulfite

It is important to know if the reaction of acylating agents with the secondary functional groups on protein can be modified by use of chemicals that might be acceptable food additives. Sulfite, a widely used additive, has been shown by Pfleiderer et al. (1968) to protect all of the sulfhydryl groups in lactate dehydrogenase during the acetylation with acetylimidazole.

To evaluate the inhibitory effect of sodium sulfite on acylation of secondary groups, fish myofibrillar protein was acylated with acetic and succinic anhydride in the presence of up to 20 m*M* sulfite. As the results of Figures 1

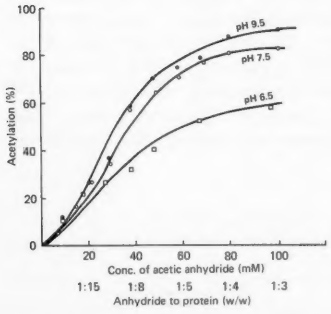

Figure 4.—The reactivity of sulfhydryl group of fish myofibrillar protein with acetic anhydride (protein content, 30.2-31.6 mg/g).

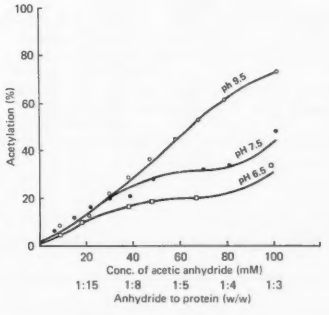

Figure 5.—The reactivity of hydroxyl group of fish myofibrillar protein with acetic anhydride (protein content, 30.2-31.6 mg/g).

and 2 and Table 3 indicate, sodium sulfite was effective in retarding the reaction with sulfhydryl, tyrosyl, and the amino group. In contrast to the result of Pfleiderer et al. (1968), however, the sulfite was more effective in retarding the reaction of tyrosyl than the sulfhydryl group. There was decreased acylation of the amino group and protection of the hydroxyl and sulfhydryl groups. In general, the protection effect was increased with higher levels of sodium sulfite (Table 3). However, the effect differed depending on the kinds of secondary group. For example, acylation of tyrosyl groups was completely inhibited at a level of 15 m*M* of sodium sulfite while acylation of sulfhydryl and hydroxyl was reduced to approximately 50 percent at 5 m*M* of the sulfite and higher levels of sulfite did not retard the reaction further. The retardation effect was greater for the secondary groups than for the amino group. At a level of 15 m*M* sulfite, acetylation was reduced 20 percent on the amino group, 70 percent for total secondary groups, 60 percent on the sulfhydryl, 55 percent on the hydroxyl, and 100 percent on the tyrosyl groups.

Sulfite, as shown in Table 4, was also effective in reducing the succinylation of protein functional groups. A significant retardation of succinylation of the sulfhydryl group occured in the presence of sulfite, while the reaction of the hydroxyl group was not greatly affected. Succinylation of the tyrosyl group was not detected as other investigators have reported earlier (Riordan and Vallee, 1964; Gounaris and Perlmann, 1967). Although the extent of succinylation was lower than acetylation, the protective effect was revealed almost the same as in the case of acetylation. Fifteen m*M* sulfite reduced succinylation 37 percent on amino, 60 percent on sulfhydryl, and 28 percent on hydroxyl groups.

The pH dependence of the retardation effect of sodium sulfite is shown in Table 5. A major decrease in the acetylation of amino and tyrosyl was shown below pH 7.5; however, there were only minor changes for sulfhydryl and hydroxyl.

From these results it is concluded that sulfite can be used effectively to retard acylation of secondary groups; however, it may be less useful for succinylation reactions since only the sulfhydryl reaction is significantly retarded with the acylation agent. For example, acetylation with an anhydride to protein ratio of 1:10 at pH 9.5 results in 80 percent acetylation on amino and 25 percent on total secondary groups that include 18 percent on tyrosyl, 46 percent on sulfhydryl, and 22 percent on hydroxyl (Fig. 1). The same level of acetylation on amino group was obtained at an anhydride to protein ratio of 1:5 with 15 m*M* sulfite at pH 9.5 (Table 5); however, acetylation was reduced 24 percent on secondary groups that include 60 percent reduction on tyrosyl and 13 percent on sulfhydryl, but little or no change in hydroxyl.

Discussion

The results of acetylation with acetic anhydride show that the amino groups of fish myofibrillar proteins were readily acetylated to a level of 80-90 percent under relatively mild conditions. However, the overall reactivity of secondary groups, particularly hydroxyl, was much less than that of the amino group, a function of pH and reagent concentration. The effect of pH on the reaction rate of protein

Table 3.—Effect of sulfite on acetylation of functional groups in fish myofibrillar protein at pH 7.5.

Sodium sulfite (m*M*)	Acetic anhydride (m*M*)	Percent acetylation on: Amino group	Total secondary groups	Tyrosyl group	Sulfhydryl group	Hydroxyl group
0	100	94.8	78.2	95.1	95.1	69.7
5	97	88.4	28.7	26.5	46.3	28.0
10	106	83.8	26.2	13.2	40.2	30.7
15	107	78.3	22.2	0	40.2	30.3
20	107	75.0	20.8	0	39.0	28.3

Table 4.—Effect of sulfite on succinylation of functional groups in fish myofibrillar protein at pH 7.5.

Sodium sulfite (m*M*)	Acetic anhydride (m*M*)	Percent succinylation on: Amino group	Total secondary groups	Tyrosyl group	Sulfhydryl group	Hydroxyl group
0	95	80.8	6.6	0	36.6	6.7
5	86	70.9	5.6	0	28.0	6.0
10	86	66.3	5.4	0	15.9	6.2
15	86	51.2	4.1	0	15.9	4.8

Table 5.—The influence of pH on the retardation of the acetylation of fish myofibrillar protein in the presence of sulfite.

pH	Sodium sulfite (m*M*)	Acetic anhydride (m*M*)	Percent acetylation on: Amino group	Total secondary groups	Tyrosyl group	Sulfhydryl group	Hydroxyl group
6.5	15	60	33.2	9.2	0	36.8	11.7
7.5	15	60	75.0	12.9	5.2	37.8	14.0
9.5	15	60	79.6	19.2	7.0	41.5	22.6

residues tended to reflect, as generally recognized, that the acetylation reaction was more favorable at pH 9.5 than at pH 7.5 or 6.5. The pH effect on the reaction rate was greater on the secondary groups than on the amino group at higher levels of anhydride, whereas at lower levels of anhydride concentration, the differences were very small.

Tyrosyl showed a large increase in acetylation rate at higher levels of anhydride. Also, a large decrease in the acetylation of tyrosyl occurred in the presence of sulfite. This large increase in acetylation rate might be explained by exposure of buried tyrosyl groups as a result of acetylation-induced conformational changes in the protein (Habeeb, 1966). The decrease in the acetylation of tyrosyl in the presence of sulfite might be due to a sulfite-induced conformation change in protein as was suggested by Pfleiderer et al. (1968).

Conclusions

Protein amino groups were readily acylated under mild conditions at pH 9.5 to 6.5 with 30 to 50 m*M* anhydride (ratio of anhydride to protein, 1:10 to 1:5, weight:weight) added at the rate of 0.5 g/minute resulting in 80-90 percent acetylation. Under the same conditions, the reactivities of secondary groups were much less; only 20-30 percent as total secondary group, 20-35 percent of tyrosyl, 40 percent of sulfhydryl, and 20 percent of hydroxyl groups were acetylated. Sodium sulfite was effective in retarding the acylation of these secondary groups. Fifteen m*M* sulfite reduced acylation by 20 percent on amino, 60 percent on sulfhydryl, 100 percent on tyrosyl, and 55 percent on hydroxyl groups; and 15 m*M* sulfite reduced succinylation by 37 percent on amino, 60 percent on sulfhydryl, and 28 percent on the hydroxyl group.

The relative acylation reactivities of protein groups might be considered in terms of the modification of proteins for food use. In much of the reported work on food-protein modification, about 80 percent acylation of the amino group is indicated. If 80 percent acylation of the amino group is used as an example and if minimal amounts of secondary products are desired, it is recommended that the reaction conditions be pH 9.5 with an anhydride to protein ratio of 1:10. Under these conditions, acylation would result on 20-30 percent of the total secondary groups that include 20-30 percent tyrosyl, 40 percent sulfhydryl, and 20 percent hydroxyl groups. It is further recommended that when the need for the least secondary product is indicated, then the acylation should be performed in the presence of sulfite.

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Radio Tracking Juvenile Marine Turtles

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ABSTRACT — A "head-starting" program for aiding the population recovery of endangered marine turtles has been evaluated by the use of radio tracking. Tracking hardware, aircraft installation, and procedures are described.

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Introduction

Five species of sea turtles are indigenous to the Caribbean and the Gulf of Mexico. For a variety of reasons, they are all in relative danger of extinction and, as such, are protected by the provisions of the Endangered Species Act of 1973. Reasons for the population decline are: Commercial exploitation for meat, eggs, and shells; habitat destruction by man; natural predation; and incidental capture in fishing trawls.

One approach being evaluated to replenish stocks of marine turtles is called "head starting." The rationale behind head-start programs is to reduce high hatchling mortality rates experienced in wild turtle populations by rearing turtles in captivity to an age when mortality is significantly reduced. A head-start program for the Atlantic ridley, *Lepidochelys kempi,* was initiated jointly by the United States and Mexico in 1978. In this program, eggs are collected from nesting grounds near Rancho Nuevo, Tamaulipas, Mexico, for incubation and hatching. To allow for possible imprinting for future nesting migrations, the newly hatched turtles are permitted to enter the water at these locations. There the hatchlings are collected and transported to the Galveston (Tex.) Laboratory of the National Marine Fisheries Service's Southeast Fisheries Center (SEFC), where they are raised in a protected environment. The young turtles are released in known habitats of juvenile turtles, such as the lower Gulf of Mexico or off the west coast of Florida.

The first few months after release are critical for head-started turtles, as they must adapt to the natural environment. Thus, information on the activity of the turtles during this period will aid in evaluating the initial success or failure of the release. One technique to acquire information is radio tracking.

A radio-tracking system was developed by the SEFC's National Fisheries Engineering Laboratory, NSTL Station, Miss., for head-started turtles. The goal was to develop a system to provide reliable information concerning movement and behavior patterns of juvenile turtles.

Specific steps for developing a radio-tracking system included a review of past problems associated with radio-tracking experiments, development of an improved radio-transmitter package design, demonstration that the transmitter did not interfere with normal turtle activities, and a demonstration that the system was suitable for short-term (30 days) tracking experiments.

Preliminary Study

Movements of several juvenile loggerheads were monitored for over a week. Each turtle was tagged with a miniature pulsed radio frequency transmitter sealed in hollow plastic cork. The corks were attached to the trailing edge of each turtle's carapace with a length of braided linen line equal in length to the turtle's carapace. The transmitters were tracked in a light aircraft using standard radio direction-finding techniques. Even though the approach was successful, several problems were noted:

1) Several transmitters broke away from the turtles due to failure of the attachment lanyard. The detachment problem was due presumably to abrasion of the linen lanyard by the edge of the carapace. A more durable material would need to be identified for the attachment lanyard.

2) A transmitter malfunctioned for unknown reasons. This malfunction was believed due to saltwater incursion, dictating the need for better package sealing.

3) Transmitter damage was caused by the turtles biting them. This damage could be prevented only by making the attachment lanyard substantially shorter than the carapace length. Shortening of the lanyard, however, somewhat defeats the purpose of the lanyard approach, which is to provide antenna exposure above the water surface even when the turtle has not fully surfaced. It was not felt that a satisfactory solution to this problem existed, but the effects could be minimized.

4) There was a lack of sufficient radio tracking range. The transmitter range limitation was due to the low output power from the transmitter imposed by state-of-the-art of transmitter miniaturization, to state-of-the-art receiver limitations, and to the size package a juvenile turtle could be expected to carry. Use of a higher gain, more directional antenna, and improvements in receiver performance could increase the transmitter range.

5) There was a lack of adequate aircraft search range. The use of a larger, twin-engine aircraft would extend the range of search coverage, thereby eliminating this problem.

System Description

The final tracking system selected was comprised of a small transmitter

float towed by the turtle and a tracking receiver, antenna system, and Loran-C navigation receiver installed in tracking aircraft.

Transmitter

Based in part on the previous juvenile turtle tracking work, commercially available transmitters, from Wildlife Materials, Inc.[1], were selected for use. Criteria used for selection of the transmitters were output power, battery life, size, and weight.

Before release, behavior studies were conducted on the amount of time tagged and untagged juvenile Atlantic Ridley turtles spent beneath the surface of water in 200-liter tanks. Also observed were the number of dives and the number of times the turtles were successful in capturing live prey (shrimp and minnows). These studies failed to show any statistically significant difference in behavior between tagged and untagged turtles. Also, the attachment lanyards that were slightly shorter than the carapace of the turtle were optimum for maximizing exposure time of the antennas, and at the same time, avoiding bite damage by the tagged animal. The turtles to be tracked were expected to weigh approximately 484 g when released.

Considerable effort was expended to improve hydrodynamic characteristics of the transmitter float. Principal shortcomings of previous designs related to the amount of drag evident to the tagged animal and a characteristic tilting of the antenna when the turtle swam. A variety of float models were constructed and evaluated in a hydrodynamic flow tank. These included hemispheres, sections of ellipses, several boat shapes made from two sections of hemispheres, ellipses, and several triangular shapes. Attachment paints and weight distributions were varied. The shape selected from this evaluation was the triangular pyramid (Fig. 1). This design provided good underwater stability, minimal drag (most of the other shapes tumbled and twisted when towed) and it maintained the antenna in a vertical position even when towed with the antenna partly submerged.

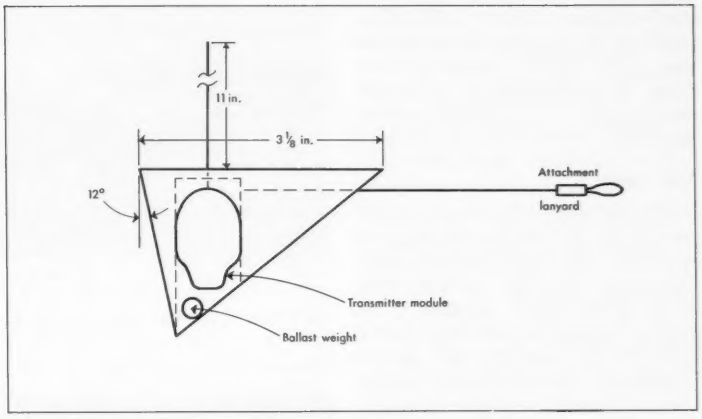

Figure 1.—Transmitter package assembly.

Figure 2.—Juvenile turtle with radio transmitter float.

The transmitter module, as received from the manufacturer, is an oblong blob weighing 8 g. It consisted of a hermetically sealed transmitter with two mercury battery cells encapsulated in an acrylic plastic. This module was then installed in the triangular pyramidal float and sealed with silicone rubber. This assembly (shown attached to a turtle in Fig. 2) had a total weight of 28 g. The transmitter radio frequency power output in saltwater was averaged -7 dbm with a capability of 45 days of continuous operation. On-off control was provided by a normally closed reed switch held off by a magnet taped to the top of the transmitter.

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Attachment to the edge of the turtle's shell was made with a No. 6 stainless steel wire. Sixty pound test monofilament nylon was later found to be a better choice because of problems with corrosion or fatigue of the stainless steel.

Receivers

The tracking receiver was purchased from the same manufacturer as the transmitter. This receiver has an exceptionally high-gain (130 dB), low-noise performance, enabling it to receive very weak signals. The receiver is battery operated and, thus, was independent of the aircraft power system. Tuning the receiver to enable it to receive the signals from different transmitters was done via digital thumbwheel switches. This was an extremely worthwhile feature for aircraft operation since it was necessary to track many transmitters simultaneously.

Antenna System

The most critical part of the tracking system, particularly when tracking these extremely low power transmitters, is the antenna installation. Slight changes in antenna mounting can produce great variations in system sensitivity and tracking range. Because of the requirements of area tracking coverage, a small twin engine aircraft was necessary. Unfortunately, all small twins that were available for lease were of the low-wing design. This posed severe problems in antenna mounting.

The commercially available tracking antennas are all variations of yagi antennas. They provide a good tradeoff between simplicity of construction, durability, and sensitivity. The model selected for our experiment was a 3-element yagi. The longest rear element was 36″ long and the boom was 42″ long. This was a vertically polarized antenna, and to receive the vertically polarized transmitted signal, it needed to be mounted vertically. This was a physical impossibility on the low-wing aircraft.

The resulting installation for the first experiment was to mount the

Figure 3.—Tracking aircraft.

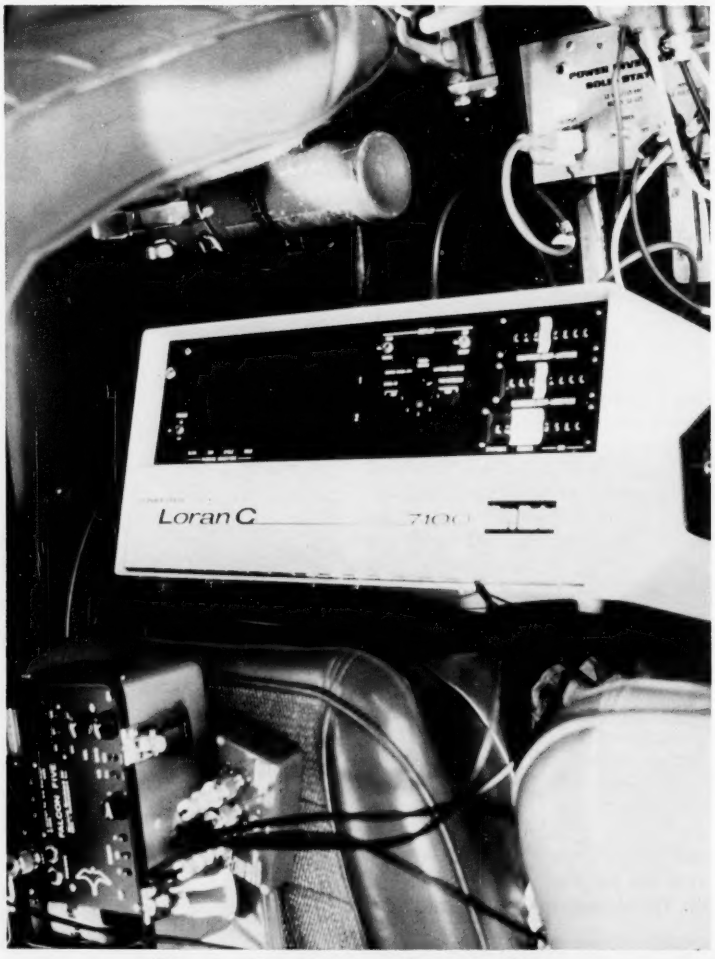

Figure 4.—Aircraft interior equipment installation.

antennas horizontally, one on each wing with the sensitive axis directed toward the wingtip. They were connected to the receiver with a two-position selector switchbox. Although this worked, it yielded a tracking range of only about 7 miles. This configuration is shown in Figure 3.

Measurements in the lab indicated that there is about 12 dB reduction in gain with the antennas mounted in the horizontal versus the vertical orientation. Since the antenna gain is only about 8 dB to begin with, this meant that the horizontal performance was 4 dB down from a simple dipole. So, for a second experiment, a quarter-wave whip antenna was added to the belly of the aircraft and selected by a third position on the switchbox. This increased the tracking range to 30 miles — much more than the 4 dB difference theoretically indicated. The mode of operation, since the whip was not directional, was to make the original detection with the whip and then switch to the yagis for direction finding.

Aircraft Navigation

Aircraft position information was obtained with Loran-C receiver (Micro-Marine Model 7100). The receiver automatically displays latitude and longitude, measures 19″ x 10″, and weighs 33 pounds. It was mounted to seat rails in the aircraft after the spare seat had been removed (Fig. 4). Power (115 V) for the unit was provided through a 300 W inverter from the aircraft's 12 V electrical system. The aircraft's ADF antenna was used for the system and was found to provide an adequate signal for operation in relatively remote areas where the turtles were released. Some interference was noted, however, in areas of electrical activity, such as near power sources and major airports.

Florida Bay Experiment

The first experiment was conducted in western Florida Bay in the vicinity of the Everglades. Two groups of six radio transmitter-tagged turtles were released.

The first group of turtles was released on 28 February 1979. Their transmitters were provided by two commercial manufacturers. All three of the transmitters from one supplier failed shortly after release. The three transmitters from Wildlife Materials, Inc., were tracked for 9 days, and then were recovered by boat after having broken loose from the turtles. Separation was due to fatigue or corrosion of the stainless steel leader at the reinforcing ferrule in the balsa wood float. During the 9-day tracking period, there was an absence of any interruption in the transmitter signals, which, if present, would have indicated that the turtle was diving. It was impossible to determine exactly when the transmitters detached, but it was generally agreed that detachment occurred shortly after release.

The second group of turtles was released on 6 March 1979, in the vicinity of Sandy Key. As in the earlier experiment, six radio-tagged turtles were released. All transmitters were from Wildlife Materials, Inc. The turtles spent most of the time submerged, with only brief periods at the surface. This made tracking difficult because transmitter contact could only be maintained for a few moments. Each day, approximately three turtles were located, but different individuals would comprise the group. After a 6-day tracking period, the turtles were within 10 miles of the release point. A boat, equipped with a hand-held tracking receiver, was dispatched to verify that the transmitters were still attached to the turtles. This verification was made for one turtle that was kept in visual contact for approximately 1 hour. The turtle appeared to be acting normally.

Homosassa Experiment

The second field experiment was conducted in the Gulf of Mexico adjacent to Homosassa, Fla. To minimize flying time and extend the tracking period, all of the instrumented turtles were released in one group. This was done just offshore from Chassahowitzka Point on

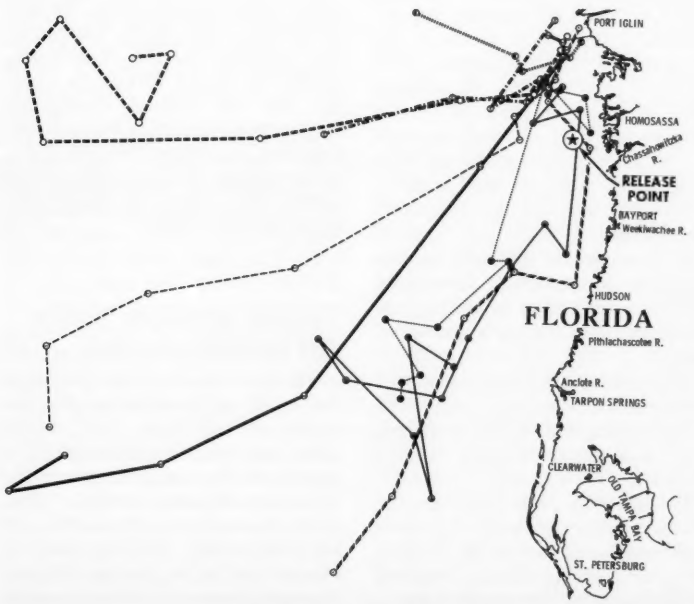

Figure 5.—Turtle tracking data.

8 May 1979, when 10 radio-tagged turtles were released with about 1,500 other turtles. Aircraft tracking was conducted daily for the first 10 days, and then for 3 days to conserve aircraft time and provide relief for tracking personnel. Tracking resumed on an alternate day schedule with 4 of the original 10 turtles being tracked until the 21st day after release. At this time a 1-week break was taken. Tracking resumed 30 days after release with only two of the turtles being located. A vessel was dispatched to verify the attachment of the transmitter to one of the turtles. The transmitter was recovered without being attached to the turtle. Detachment was caused by a broken attachment lanyard. Detachment apparently occurred just before recovery since signals were continuous on the day the transmitter was retrieved, and intermittent on the previous day, indicating that it was attached to a diving animal.

A second vessel was dispatched to locate and verify attachment of the second transmitter; however, verification was not possible due to behavior of the animal. Apparently, the turtle had become sensitive to noise and would dive when approached by the vessels or the search aircraft at low altitudes. This made it impossible to precisely locate the animal. Tracking data from this release are given in Figure 5. The points shown are the aircraft-determined locations at various intervals averaging about every third day. During the 30-day tracking period, some of the animals ranged to a distance of 150 miles offshore.

Results and Conclusions

The experiments were successful in meeting most of the major objectives. Most problems observed with previous tracking attempts were solved. Premature detachment of the transmitter module was a problem with the stainless steel attachment leader. This was solved with the use of monofilament nylon. There was no evidence of detachment with the nylon lanyard.

A remaining problem is with the transmitter package design, which allows the turtle to reach the antenna tip and bite it, causing a pigtail curl in the tip. Fortunately, this had no detrimental effect on transmitter range.

The most significant remaining problem is the limited tracking range due to the receiver antenna mounting on the aircraft. Because most experiments probably will rely on leased aircraft, an antenna system that will mount on any type of aircraft would be desirable.

Acknowledgment

The author gratefully acknowledges James P. McVey, SEFC, Galveston Laboratory, for providing biological consultation and turtles.

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NOAA/NMFS Developments

National Climate Plan Published by NOAA

A 5-year plan to reduce the adverse effect of climatic conditions on the economy and environment, including fisheries, has been released by the Commerce Department's National Oceanic and Atmospheric Administration (NOAA). Prepared by the National Climate Program Office, the plan's goal is to help avert weather-related problems such as food and fuel shortages through improved forecasting and more efficient dissemination of climatic data.

Funds will be drawn from appropriations 11 of the 17 participating agencies receive for climate-related activities. The proposed 1981 budget is $126.7 million. Specific goals of the plan include:

1) Insuring that industries such as farming, construction, recreation, shipping, and fishing receive improved climatic data and use it more effectively;

2) Assessing the effect of increased carbon dioxide on the climate;

3) Studying the extent to which solar and earth radiation modify climatic conditions, and

4) Gathering more data on the oceans' roles in climate formation.

Edward Epstein of NOAA is director of the National Climate Program. Participating in the project are 11 Federal departments, the Agency for International Development, Council on Environmental Quality, National Aeronautics and Space Administration, National Science Foundation, the Environmental Protection Agency, and the Federal Emergency Management Agency. Copies of the plan may be obtained from NOAA's Environmental Science Information Center, 6009 Executive Boulevard, Rockville, MD 20852.

Tagged Albacore Taken Off Hakalau, Hawaii

The first recapture in Hawaiian waters of an albacore caught and tagged off San Diego, Calif., over 2 years ago, has been reported by Richard S. Shomura, Director of the Southwest Fisheries Center's Honolulu Laboratory. According to Howard Takata, the University of Hawaii Sea Grant's Marine Advisory Specialist stationed in Hilo who made arrangements for the return of the tag, the fish was one of nine albacore

caught off Hakalau, Hawaii, by Marlon Pacheco fishing from his boat, the *Dawn L* on 15 October.

Fishery scientists at the Southwest Fisheries Center's La Jolla Laboratory in California have been routinely tagging albacore in California waters for a number of years. To date, 25-30 of these tagged fish have been recaptured by Japanese longliners in the North Pacific. About a dozen tagged fish have been taken in Hawaiian waters but Pacheco's fish is the first tagged albacore caught in the local "ika-sibi" fishery.

Pacheco's albacore was first caught on 25 July 1978 south of San Diego at lat. 31°31'N, long. 118°33'W by a California baitboat (pole-and-line fishing boat). The fish was 32 inches (81 cm) long (fork length) and weighed 26 pounds (12 kg) when tagged and was about 41 inches (106 cm) long and weighed 54 pounds (24 kg) when caught by Pacheco. The straight line distance from the point it was tagged and released to where it was recaptured off Hakalau is approximately 2,100 nautical miles. Since albacore are known to make transpacific migrations between the U.S. west coast and Japan, Shomura speculated that this fish may have made a crossing from California waters to Japan before arriving in Hawaii during the approximately 27 months it was at liberty.

Pacheco received a $2.00 reward rather than a $50.00 reward which was contingent on the return of the fish's head. The value of the head of this particular fish lay in the fact that the fish was one of many, at the time of release, that had been injected with the antibiotic tetracycline for age and growth studies. The tetracycline injection produces a mark on the fish's otoliths (ear bones) which is used as a reference point to count the growth rings.

Because fishery scientists are continuing to tag and release albacore not only off California but also off Japan, local fishermen are urged to carefully examine their catches for tags. Fishery scientists at the La Jolla Laboratory use a red tag to identify fish injected with tetracycline. Information obtained from these tagging experiments provide much vital information on the life history of these valuable commercial fishes, said Shomura.

Marine Fish May Use Tiny "Magnets" to Navigate

Preliminary results of research on tunas and green turtles indicate that small "biological magnets" in the frontal part of the skull may help explain the species' remarkable navigation abilities, reports Richard S. Shomura, Director of the NMFS Southwest Fisheries Center's Honolulu Laboratory. The research is being conducted by University of Hawaii graduate students Michael Walker and Anjanette Perry together with Andrew E. Dizon of the Honolulu Laboratory and J. Kirschvink of Princeton University.

The mystery of how migratory animals can navigate accurately over great distances has long puzzled biologists. Studies on the navigation of migratory birds and homing pigeons, however, have revealed a surprising ability of these birds to sense the geomagnetic field of the Earth and to use it to guide their travels. This geomagnetic "map" seems to be accurate to within about 5 km (3 miles) over most of the Earth's surface and hence may be one of their most important sensory tools.

When these magnetic effects were discovered, no plausible mechanism through which animals might detect and use the weak geomagnetic field was known. Recently, however, a surprising variety of animals including bacteria, honeybees, pigeons, and dolphins have been shown to synthesize small crystals of magnetite or lodestone, a mineral containing iron. The tiny, iron-rich particles in the body of the animals act like simple compass needles in the Earth's magnetic field and may be the key to the sensory mechanism which guides the animal's incredible migratory behavior.

Using the paleomagnetic facilities at the Hawaii Institute of Geophysics, including an ultrasensitive magnetometer utilizing a liquid helium temperature device which can detect the presence of microscopic amounts of magnetite anywhere in a tissue sample, Walker, Perry, Dizon, and Kirschvink recently conducted a joint search for similar magnetic crystals in migratory Pacific tunas and green turtles. They used nonmagnetic dissecting tools such as plastic picnic knives and shards of glass and found tens of millions of magnetic crystals in the head of these animals — enough material to provide tunas and turtles with an extremely accurate magnetic map sense. In the tunas (yellowfin, skipjack, and kawakawa) the magnetic material was very precisely and repeatedly isolated in or upon the frontal bone of the skull, said Dizon.

This discovery of the small biological magnets suggests that a magnetic sense ought to be looked for in animals. In experiments conducted at the Kewalo Research Facility, Walker and Dizon have already discovered an unconditioned magnetic response in yellowfin tuna, and Perry is experimenting to see if such a response can be detected in green turtle hatchlings. Detailed Pacific-wide data on magnetic lineations on the sea floor and magnetic storms produced by solar winds are available, and it would be interesting to determine whether these magnetic parameters influence the migratory patterns of marine animals, said Shomura. If these migratory patterns of marine animals are indeed correlated with these magnetic parameters, these studies could be of great value in predicting the distribution and movements of commercially important fishes such as the tunas, concluded Shomura.

These experiments to detect unconditioned magnetic responses in marine animals are but a few of the many important research activities that are continuing at the Kewalo Research Facility. Past research at the facility has not only provided new scientific data on the behavior and physiology of the tunas but has also provided much practical aid to the local fishing industry, said Shomura.

Japan's Use of Processed Fish Products Declines

Climbing retail prices of fresh seafood and reduced consumption of fish has resulted in a 2 percent decline in processed fishery foodstuffs from 1976 to 1979, according to a report by Japan's Food Industry Center.

The household yearly expenditure for processed foodstuffs in 1979 was ¥367,122 ($1,671 @ US$1 = ¥219.7) and was 45 percent of all food expenses. When restaurant expenditures were excluded, processed food expenses represented 52.8 percent of all food expenses. Of all processed foods, 16.8 percent was fish, and 18.2 percent was bread and confectionary goods. The 1979 fisheries foodstuff expenditure was ¥61,705 ($281).

The lowest annual consumption of canned seafood per household (9.0 cans) occurred in 1970. The sales have since increased to 14.6 cans in 1979. Seaweed consumption showed a decrease in kelp (kombu) and an increase in wakame, which doubled from 1970 to 1979. The ingredient most liked in miso soup was wakame. Due to price increases and changes in tastes, there has been an actual decrease in dried seaweed consumption since 1975.

Consumption of all fish paste products (kneaded products) has decreased. In addition to the change in consumer tastes, there was a 50.4 percent and a 48.5 percent large-scale price increase during the 4-year period, for both fried fish balls (satsuma age) and broiled pollock (kikuwa). Compared with previous years, the import volume of fishery foodstuffs such as salted salmon and cod roe increased in 1979.

Such primary seasoning ingredients as the small dried sardines (since 1964) and dried skipjack (katsuo) seasoning (after 1977) have shown a decline in sales, but there are indications that this situation will not last. Consumption of eel/loach (kabayaki), in comparison with previous years, has had an actual increase of 8.4 percent. All eel consumption has shown large-scale actual increases. (Source: LSB 80-20.)

Japanese Fishermen's Income Up 8.8 Percent

The average houshold income for Japanese fishermen in 1979 was ¥4,360,000 (US$19,845 at US$1 = ¥219.7) and was up 8.8 percent, according to Japan's Ministry of Agriculture, Forestry, and Fisheries. This increase resulted from a 5.7 percent increase in fishing industry revenues as well as a 14.8 percent salary increase (wages, pension, subsidies, and compensation money). The 8.8 percent increase exceeded the rate of increase of both farm household income of 5.5 percent and the national laborers' household income of 7 percent.

Fishing industry revenues have increased due to a climb in wholesale production prices. This increase, however, was offset by the rise of fuel and expenditures. Subsequently, the increase in revenues was only 5.7 percent. Fishing industry revenues showed a 4.1 percent decrease in 1978 due to low fish prices as compared with previous years. In 1979, however, the 1977 fishing industry revenues were recovered.

Family houshold expenses were ¥2,890,000 (US$13,154), a 6.2 percent increase over previous years. Per capita household actual expenses were ¥672,900 (US$3,059), a 6.4 percent increase over the previous year. Subtracting household expenses from net income (fisherman income minus several taxes), the disposable income was ¥1,027,000 (US$4,675) a 14.4 percent increase over the previous year. (Source: LSB 80-22.)

Netherlands Antilles-U.S. Fisheries Trade Increases

Netherlands Antilles 1979 fishery exports to the United States totaled 11,800 t and were valued at US$10.3 million, an increase of 53 percent in quantity and 30 percent in value over

Table 1.—Netherlands Antilles exports to the United States, 1978-79, in metric tons and US$1,000.

Commodity	1978		1979	
	Quantity	Value	Quantity	Value
Edible				
Live lobster	10.7	45.9	7.5	32.3
Frozen				
Tuna				
Yellowfin				
Whole	2,663.3	2,301.9	5,354.4	4,821.1
Evisc.	—	—	2.7	2.7
Albacore	1,911.7	3,076.3	125.2	201.9
Skipjack	3,095.9	2,445.7	6,234.2	4,979.3
Other[1]	4.6	15.2	—	—
Shrimp	—	—	18.9	95.6
Other				
Shellfish	—	—	1.1	4.1
Canned				
Tuna			37.5	67.5
Shrimp			3.0	37.5
Cured shark fin	5.7	29.4	Negl.	1.5
Total	7,691.9	7,914.5	11,784.5	10,243.5
Inedible				
Ornamental fish		3.2		14.8
Total	Negl.	3.2	Negl.	14.8
Grand total[2]	7,691.9	7,917.7	11,784.5	10,258.3

[1] Fillets.
[2] Totals may not agree due to rounding.
Source: Bureau of the Census, U.S. Department of Commerce.

the 1978 figures (Table 1). Tuna exports, however, mainly yellowfin and skipjack tuna, were 99 percent of the 1978 and 1979 total.

The NMFS Foreign Fisheries Analysis Division believes these shipments to be almost entirely tuna caught in the eastern Pacific by Netherlands Antilles-flag vessels and transhipped to the United States. It is unlikely that any of the tuna seiners registered in the Netherlands Antilles actually landed their catch on the islands for processing. The Netherlands Antilles tuna fleet consists of 8 tuna seiners with a total carrying capacity of 8,500 t. Five of these vessels, however, have recently been sold to a Mexican-United States joint venture company, Pescatun.

Fishery imports from the United States also increased with 1979 imports totaling nearly 900 t valued at US$3.2 million. This was a 13 percent increase in quantity and a 19 percent increase in value over 1978 imports (Table 2). The Netherlands Antilles is the third most important Latin American importer of U.S. fishery products; only Venezuela and Colombia imported more in 1979. The Division believes, however, that an unknown quantity of these imports are not consumed in the Netherlands Antilles, but were transshipped to other countries in the Caribbean. (Source: IFR-80/152.)

Table 2.—Netherlands Antilles fishery imports from the United States, 1978-79, in metric tons and US$1,000.

Commodity	1978 Quantity	1978 Value	1979 Quantity	1979 Value
Edible				
Fresh or chilled				
Shellfish				
Shrimp				
Packaged	1.9	12.0	5.4	21.2
Unpackaged	0.8	8.5	—	—
Other	0.1	0.6	2.2	36.4
Frozen[1]				
Fish				
Salmon				
Whole and eviscerated	1.8	13.7	1.3	14.3
Fillets, Steaks, portions	1.2	8.0	2.0	24.2
Other				
Fillets	37.8	147.0	114.3	302.6
Sticks and portions	3.9	12.2	12.6	45.6
Other	524.1	1,310.4	496.8	1,705.8
Shellfish				
Shrimp	19.5	187.9	23.5	246.4
Crab				
King	3.9	41.7	2.6	40.3
Snow	1.6	16.4	0.3	3.3
Other	26.8	218.8	61.0	346.4
Canned				
Fish				
Salmon				
Cured	1.6	56.1	7.8	32.1
Other	21.7	66.6	22.0	65.5
Sardines	9.1	22.1	33.5	49.4
Mackerel	36.3	191.2	31.6	131.0
Other	10.7	25.5	4.2	6.8
Shellfish				
Shrimp	18.3	99.4	6.6	39.4
King crab	0.1	1.2	0.1	1.9
Cured				
Fish	7.3	39.2	17.9	95.3
Shellfish	6.7	42.2	1.2	6.9
Other				
Fish				
Airtight containers[2]	22.6	93.5	17.7	66.6
Roe	13.5	81.7	6.4	40.2
Other	0.4	1.9	0.9	3.6
Shellfish	3.9	17.8	5.8	29.9
Total	775.6	2,715.6	877.7	3,237.3
Inedible				
Ornamental fish	N/A	3.9	N/A	1.3
Other	N/A	3.9	N/A	1.2
Total	N/A	7.8	N/A	2.5
Grand total	775.6	2,723.4	877.7	3,239.8

N/A = Not available.
[1] May include small amounts of fresh and chilled fish.
[2] Other than canned.

Ecuador May Export Herring to Europe

Ecuadorean fishermen caught a record 615,000 metric tons (t) of fish and shellfish in 1979, most of which was reduced to fish meal. About 90 percent of this catch was small pelagic species, mostly Pacific thread herring, *Opisthonema libertate*[1]. The fishery is conducted primarily in the Gulf of Guayaquil.

The thread herring fishery developed rapidly during the 1970's. Ecuadorean fishermen only caught about 35,000 t of thread herring, known locally as "pinchagua," in 1970. Most of the catch is reduced to fish meal and the Government has expressed considerable concern about the rapid development of this fishery.

In late August 1980, the Ecuadorean Government announced its first action to limit the expansion of the fishery. Government officials announced the closing of two fish meal reduction plants owned by DURAMINA and MARIMAR. The two plants were located on the Santa Elena Peninsula near the port of Chanduy. The companies were charged with expanding their reduction facilities without authorization of the Subsecretariat of Fisheries.

Some of the thread herring catch is canned for the domestic market and for export, principally to Colombia. The Subsecretariat of Fisheries would like to see a larger proportion of the catch canned to produce the more valuable edible product.

Fisheries economist Albert Elissat, from the European Economic Community, has reportedly studied Ecuador's thread herring fishery and has recommended sweeping changes. Elissat has informed Ecuadorean officials that canned products made from species similar to thread herring are popular in Europe. Declining stocks of similar species in European waters have made it impossible for European fishermen to adequately supply their domestic market. Elissat has recommended that Eduador can more of the thread herring catch and attempt to market it in Western Europe. (Source: U.S. Consulate General, Guayaquil, and IFR-80/157.)

[1] Additional information on this fishery can be obtained by requesting IFR-80/54 from your local NMFS Statistics and Market News Office, enclosing a self-addressed and stamped envelope.

Supermarkets Are Top Fish Retailers in Japan

While Japanese fresh fish retail store sales were more than ¥20 million ($91,033 at $1 = ¥219.7), supermarket sales were more than ¥100 million ($455,166), according to a study commissioned by Japan's Ministry of Agriculture, Forestry, and Fisheries. They also found that the quality of fish sold at supermarkets was superior.

The research study (August-November 1979) compared 982 Tokyo and Osaka fresh fish retail stores and supermarkets. Other study

results include the following items.

1) Supermarket fishery goods transactions have increased in each of the past 5 years.

2) Sixty-three percent of the Tokyo retail stores and 54 percent of Osaka stores could stock ¥2 million ($9,103) worth of goods per month. On the other hand, half of the supermarkets could stock more than ¥10 million ($45,517).

3) Most retail stores stock a variety of 20-30 items. Tokyo stores were able to stock more than Osaka ones. The majority of supermarkets (92 percent) can stock more than 50 items and some (18 percent) can stock 200 items.

4) The majority (27 percent) of annual sales in retail stores was more than ¥10 million ($45,517) but less than ¥20 million ($91,033). Only 19 percent had a sales figure of ¥50 million ($227,583). However, the supermarkets commonly had annual sales figures of more than ¥100 million ($455,166).

5) The number of customers per day for the Tokyo retail stores was more than 50 but less than 100. Osaka stores had more than 100 but less than 200 customers daily. (No supermarket figures were given.)

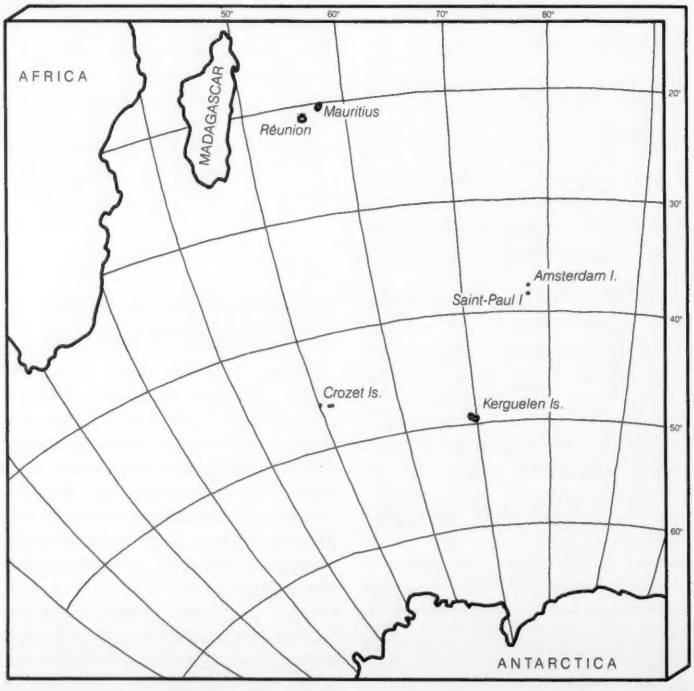
6) Frozen fish sales increased 47 percent in Tokyo and 34 percent in Osaka retail stores in the part 3 years and will continue to increase. Supermarket frozen fish sales were 30 percent and 33 percent, respectively, which are below the retail store sales.

7) Future retail store development, with the exception of frozen fish as a sideline item, may only increase 19 percent in Tokyo and 23 percent on Osaka. The problems for the retail stores include a decrease in sales, an increase in expenses, and a labor decline. (Source: LSB 80-22.)

France Monitors Fishing in Indian Ocean EEZ

The primary economic interest France now has in the region of the Indian Ocean islands collectively called the French Southern and Antarctic Lands (TAAF) lies in protecting her rights to its sea resources, now that she has declared it to be an exclusive economic zone (EEZ).

The TAAF is an immense region of the Indian Ocean (see map) comprising three island groupings: the Crozet islands, the Kerguelen islands, and the islands of Saint-Paul and Amsterdam. The climate there does not permit the installation of strategic bases. While France herself has not yet systematically engaged in fishing there, other countries — especially the USSR — have done so for years, and agreements have been reached to regulate fishing.



Four French frigates based at Reunion Island take turns patrolling the region 2-3 times a year to see to it that the terms of those agreements are observed. The harshness of the region and the lack of port facilities usually make it impossible to obtain replenishment, so that these patrols have been limited to about 1 month. However, the patrol of the *Commandant Riviere,* monitoring the Soviet fishing expedition that ended on 29 February 1980, was extended to that date by a new arrangement: The ship received replenishment from the *Marion Dufrosne,* owned by a French firm and chartered by the TAAF. The latter ship regularly provides supplies for the scientific bases in the TAAF. (Source: LSB 80-21.)

Iceland Fish Product Exports to U.S. Soar

Icelandic exports of fishery products to the United States totaled $210

million in 1979, an increase of 27 percent over the $170 million exported in 1978 (Table 1). The value of Icelandic exports to the United States has been steadily increasing since 1977, about 20 percent annually. The quantity of these exports has also increased, from 70,400 metric tons (t) in 1977 to 86,100 t in 1979. The increase in exports is almost solely due to the larger quantity of whole and filleted frozen cod being exported to the United States.

Iceland has assumed complete control over its groundfish since the 1975-76 "Cod War" dispute with the United Kingdom and the introduction of a 200-mile fishing zone. With foreign cod catches off its shores virtually ended, Icelandic fisheries authorities imposed a complex conservation program which has allowed cod stocks to recover from overfishing. Consequently, Iceland's cod catches in the late 1970's increased modestly and in 1979 totaled an estimated 360,000 t, mainly because of the measures taken to protect the cod spawning stock. Improved cod fisheries have thus enabled Iceland to increase exports to the United States and, more noticeably to northern European countries and especially to the United Kingdom.

Iceland's most important seafood export is cod, which constituted 64 percent of the total value of all fishery exports to the United States in 1979. Exports of Icelandic cod increased about 11 percent from 1977 to 1979. The second largest component of Iceland's total fishery exports is fresh and frozen filleted cusk, which may include undetermined amounts of haddock, hake, and pollock. Exports of cusk totaled almost 12 percent of the value of iceland's 1979 fishery shipments to the United States.

Frozen filleted Atlantic perch ranked third, about 6 percent of the value of all 1979 exports to the United States. Frozen whole pollock and haddock exports ranked fourth and fifth, composing about 4 percent and 3 percent of the value of 1979 shipments to the United States, respectively. (Source: IFR-80/149.)

Table 1.—Icelandic fishery exports to the United States by quantity and value, 1977-79.

Commodity	1977 Quantity (t)	1977 Value (US$1,000)	1978 Quantity (t)	1978 Value (US$1,000)	1979 Quantity (t)	1979 Value (US$1,000)
Fresh or chilled						
Fish						
Atlantic perch	7.0	9.3	946.0	1,666.2	1,494.8	2,686.4
Flatfish	175.7	378.9	204.4	459.4	129.0	304.2
Halibut	161.3	583.1	192.3	766.6	227.4	1,005.5
Rosefish	720.4	1,071.3	—	—	—	—
Shrimp	—	—	0.5	5.1	0.1	0.3
Trout	1.4	5.7	1.4	4.5	—	—
Whiting	6.0	11.1	1.0	3.6	95.1	180.1
Wolffish	—	—	—	—	16.6	54.1
Fillets						
Cod	1.5	3.6	0.2	0.7	2.2	8.4
Cusk[1]	209.9	418.6	125.3	303.5	89.4	238.5
Other	—	—	—	—	15.6	28.5
Other	1,403.1	2,372.5	1,386.8	2,450.2	1,318.7	2,510.8
Total	2,686.3	4,854.1	2,858.8	5,659.8	3,388.9	7,016.8
Frozen						
Fish						
Cod[1]	17,685.7	35,528.9	17,654.1	37,391.1	19,257.1	40,920.8
Flounders	395.7	479.3	138.8	209.9	396.3	680.6
Haddock	2,698.7	5,603.6	4,363.2	9,524.7	3,481.4	7,503.9
Halibut	21.0	24.1	3.1	3.9	34.0	177.1
Pollock	5,037.2	6,121.9	4,353.0	6,342.2	5,678.4	8,463.9
Scallops	693.4	2,488.0	640.6	2,882.7	936.4	5,280.1
Turbot	4.9	8.0	113.1	215.8	556.8	1,005.4
Wolffish	1,541.6	3,624.6	1,175.5	3,267.4	1,119.5	3,859.4
Fillets						
Atlantic perch	2,609.5	4,546.9	1,780.3	3,478.0	5,058.3	9,860.1
Cod	26,703.6	62,599.4	30,539.8	73,922.9	33,202.3	95,573.9
Cusk	7,494.5	14,580.7	7,877.5	17,381.2	10,690.3	26,398.2
Other	22.4	36.4	13.0	23.4	21.8	60.6
Shellfish						
Lobster						
Tails	383.0	3,040.2	266.5	2,394.3	206.6	2,670.4
Other	132.3	1,428.2	143.5	1,844.9	68.4	630.4
Other	97.5	234.0	68.8	176.9	—	—
Total	65,521.0	140,344.2	69,130.8	159,059.3	80,707.6	203,084.8
Canned						
Fish						
Herring	131.7	343.9	75.4	197.6	246.6	946.6
Salmon	—	—	0.1	1.2	—	—
Sardines	2.1	5.9	6.1	10.8	3.8	13.8
Other & fish roe	132.8	323.1	84.2	190.9	133.6	394.9
Shellfish						
Shrimp						
Peeled	10.7	36.9	0.1	0.3	8.1	50.5
Sauce	194.3	1,269.6	193.5	1,492.6	97.9	984.1
Other	18.5	58.7	Negl.	0.5	—	—
Total	490.1	2,033.1	359.4	1,893.9	490.0	2,389.9
Cured and pickled						
Cod	6.8	16.0	—	—	4.5	18.6
Haddock	82.5	162.6	64.3	122.3	47.3	74.0
Hake	20.9	90.5	8.1	41.8	5.0	22.8
Herring	160.2	174.9	20.1	23.2	63.0	71.0
Salmon	Negl.	0.9	0.2	3.6	0.4	7.1
Sardines	10.8	29.3	3.0	8.4	18.1	59.6
Other						
Sauces	0.8	2.4	3.9	4.2	0.9	2.9
Other	1.6	8.2	3.6	15.6	18.7	97.4
Total	283.6	484.8	103.2	219.1	157.9	353.4
Inedible						
Fish Oil[3]	451.9	320.0	262.1	210.3	480.9	416.6
Seaweeds	0.9	0.3	13.0	3.8	34.8	15.5
Other	974.5	781.3	1,054.2	1,033.8	887.8	1,015.7
Total	1,427.3	1,101.6	1,329.3	1,247.9	1,403.4	1,447.8
Grand total	70,408.3	148,322.8	73,781.5	168,080.0	36,147.8	214,292.7

[1] Includes undetermined amounts of cusk, haddock, hake, and pollock.
[2] Includes mostly frozen, skinned, and boned cod in blocks.
[3] Includes cod liver oil.
Source: Bureau of the Census, U.S. Department of Commerce.

New NMFS Scientific and Technical Reports Published

Most of the publications listed here may be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402 (if listed as a sales item). Readers are advised to write that agency prior to ordering to determine price and availability. Prices may change and prepayment is required. Information on the availability of other NOAA publications can be obtained from the Environmental Science Information Center (D822), Environmental Data and Information Service, NOAA, 6009 Executive Boulevard, Rockville, MD 20852. When out of print, copies of the reports (either paper or microfiche) can be purchased from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22151.

NOAA Technical Report NMFS Circular 434. Tyler, James C. **"Osteology, phylogeny, and higher classification of the fishes of the Order Plectognathi (Tetraodontiformes)."** October 1980. 422 p.

Abstract

The osteology of over 160 species of fossil and Recent plectognath or tetraodontiform fishes is described and illustrated in relation to the supposed phylogeny and proposed higher classification (subfamilial to ordinal levels) of this group of approximately 320 Recent species of primarily tropical and temperate forms of the Atlantic, Pacific, and Indian oceans. The history of the classification and of the previous work on the osteology of the order is reviewed, while one new species (†*Acanthopleurus collettei,* Oligocene of Canton Glarus, Switzerland) and one new genus (†*Eotetraodon,* Eocene of Monte Bolca, Italy) are described. Comparative inclusive and exclusive definitions are given for all higher categories based on both external and internal anatomical features. The Order Plectognathi (Tetraodontiformes) is divided into two suborders, the Sclerodermi or Balistoidei and the Gymnodontes or Tetraodontoidei, with a variety of other infraordinal and superfamilial categories, and 10 families, with subfamilial groupings in 4 of the latter.

NOAA Technical Report NMFS SSRF-741. Dickinson, John J., Roland L. Wigley, Richard D. Brodeur, and Susan Brown-Leger. **"Distribution of gammaridean Amphipoda (Crustacea) in the Middle Atlantic Bight region."** October 1980. 46 p.

Abstract

The distribution and abundance of 101 species of marine benthic gammaridan amphipods are described for

Fourth Annual Tropical, Subtropical Fisheries Tech Conference Papers

"Proceedings of the Fourth Annual Tropical and Subtropical Fisheries Technological Conference of the Americas," compiled by Ranzell Nickelson II (individual authors edited their own papers), presents 29 contributions ranging from an assessment of the international fisheries scene by David James of FAO's Fish Utilization and Marketing Service to a review of the Louisiana cholera outbreak by M. W. Moody of Louisiana Cooperative Extension Service, and E. Spencer Garrett of the NMFS National Seafood Quality and Inspection Laboratory in Pascagoula, Miss.

A review of the product quality and safety research activities of the NMFS is given by Thomas J. Billy and E. Spencer Garrett. Other papers discuss shrimp boat sanitation, free liquid content of oysters, a "dip stick" method for monitoring fecal coliform levels, the potential of *Planococcus citreus* for shrimp spoilage, fluid separation of fish by shape, economic freezing of fish in a plate freezer, a centrifumatic crab machine, solar drying of mullet roe, brining mullet, extension of flounder shelf life by poly (PHMB), freezer storage of blue crabs for picking plants, deboned flesh from nontraditional Gulf of Mexico fishes, nutritive values of seafoods, fish flakes, microwave shrimp cookery, queen conch fisheries and biology, and more.

The 254-page paperbound volume is available from the Marine Information Service, Sea Grant College Program, Texas A&M University, College Station, TX 77843 for $10.00.

Dangerous Marine Species Identified

Publication of the second edition of **"Dangerous Marine Animals"** by Bruce W. Halstead has been announced by Cornell Maritime Press, P.O. Box 456, Centreville, MD 21617. The well-illustrated (16 pages of 4-color photos or drawings), 256-page volume provides a detailed and ready source of information regarding the identification, geographical distribution, habits, and noxious characteristics of marine species from around the world. All organisms discussed are identified by common and scientific name and are illustrated. The means by which they come in contact with humans and thereby inflict injury, and how one copes with such situations, is discussed. Practical first aid measures and medical treatments are described.

While research scientists may miss technical discussions of the chemical and pharmacological properties of the poisonous substances, the volume remains of considerable value to most others involved in the marine environment. The 208-page volume is indexed

the Middle Atlantic Bight region. This report is based on 669 quantitative grab samples from 563 stations on the continental shelf and upper continental slope between Cape Cod, Mass., and Cape Hatteras, N.C. The amphipod fauna from the open shelf is most completely represented, but deep-sea and estuarine species are also included. The abundance of each species is reported in terms of its numerical density. Geographic and bathymetric distributions, and sediment relationships are also reported for each species.

NOAA Technical Report NMFS SSFR-742. Husby, D. M., and G. R. Seckel. **"Water structure at Ocean Weather Station V, northwestern Pacific Ocean, 1966-71."** October 1980. 56 p.

Abstract

The oceanographic station data obtained at Ocean Weather Station V from 1966 to 1972 by the U.S. Coast Guard have been analyzed and are presented in a form suitable for water structure studies. Temperatures, salinities, and depths are given as a function of density (sigma-*t*). We used harmonic analysis as a curve-fitting technique, to obtain parameters for these properties as a function of time. The harmonic coefficients and interpolated values at the first of each month for the 6-year series are tabulated in an appendix.

We describe the temporal distributions of salinity and depth in terms of the oceanographic setting. At depths greater than sigma-*t* 26, temperature-salinity relationships remain relatively constant in time. Depth variations at these levels are attributed primarily to meanders of the Kuroshio Extension. The surface divergence, as reflected by changes in the depth of sigma-*t* 26, has no annual periodicity. The 6-year record shows that large baroclinic variability occurs at time scales of more than 55 days with largest variability occurring at the interannual scale.

Heat budget estimates show that the effects of local ocean-atmosphere exchange processes are obscured by advected properties. For example, the heat content of the layer above sigma-*t* 26 is primarily determined by the divergence of this layer and anomalies in the mean temperature are produced by heat advection rather than heat exchange across the sea surface.

NOAA Technical Report NMFS SSRF-743. Low, Loh-Lee, and Ikuo Ikeda. **"Average density index for walleye pollock, *Theragra chalcogramma*, in the Bering Sea."** November 1980. 11 p.

Abstract

The data base and an average density index (ADI) procedure for assessing walleye pollock, *Theragra chalcogramma*, abundance in the eastern Bering Sea were evaluated. The data base consisted of daily catch-effort records of individual fishing vessels in the Japanese groundfish fishery from 1964 to 1976. Variances about the annual mean catch, effort, and catch per unit effort (CPUE) data were low. Coefficient of variation of annual CPUE data was in the 1-2% range for the data base after 1969 but higher in earlier years when the number of fishing records was lower. An ADI procedure is described which takes into consideration different types of vessels used in the fishery, species mix in the catch, distribution of pollock, and fishing pattern of the fleet. Data from five vessel class-gear types that fished mainly for pollock were selected to compute ADIs in four area-time cells. An overall ADI within these cells was determined, summarizing the results by vessel class-gear types and area-time cells. From 1964 to the early 1970s, overall ADI and CPUE trends increased as a result of increased pollock abundance and fishing power of vessels. For 2-3 years during the early 1970s, abundances of pollock were at peak levels. Beginning in 1972, abundance declined but stabilized during 1975-78 at an intermediate level when 1.1 million metric tons of walleye pollock were harvested annually.

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and a list of references is provided. Cost is $15.00.

FAO, UNESCO Fisheries Publications Available

The availability of several FAO and UNESCO fisheries publications has been announced by UNIPUB, 345 Park Ave. South, New York, NY 10010. Among them are the following items.

"Proceedings of the workshop on the Phenomenon Known as 'El Nino'", a UNESCO publication ($22.50) forms part of the Proceedings of the Workshop held at Guayaquil, Ecuador, 4-12 December 1974. This volume contains translations of 10 papers contributed in Spanish by marine scientists from the region, and which were presented or distributed at the workshop in their original version. Papers discuss physiological and biological aspects of the 1972-73 "El Nino" phenomenon, water masses and primary production in the northern and central Chilean zones, physical and biological aspects of the Peru current system, a summary of the biology of the anchoveta, projected Peruvian research on the species, and more.

"Engineering Applications: 1, Installation and Maintenance of Engines in Small Fishing Vessels", FAO Fisheries Technical Paper 196, by FAO consultant Brian Mutton, is a basic handbook intended primarily to aid small boatyards, boat owners, and fishermen in developing countries, still it has a lot of sound information useful to anyone involved in working with fishing vessels.

It covers principles and installation details for various engines; stern gear; cooling, exhaust, fuel, electrical, and starting systems; controls and instruments, bilge pump and bilge systems, power take-off, etc. Finally, it discusses engine selection, obtaining parts and tools, and care and maintenance. The 127-page volume costs $7.25.

The **"Handbook of Utilization of Aquatic Plants,"** by E. C. S. Little (FAO Fisheries Technical Paper 187), is a completely revised and updated version of the author's 1968 handbook, "Utilization of Aquatic Plants" and provides an extensive review of the world literature, with an annotated listing of more than 250 books, papers, etc. on aquatic plant uses. The largest section concerns the chemical composition and productivity of various species and a large number of analytical results are quoted. Sections are included on harvesting and protein extraction.

Other sections deal with harvesting methods; use for human, livestock, fish, and aquatic animal foods; use for fertilizer, compost, mulch, etc.; and such miscellaneous uses as fuel, paper, building materials, medicines,

and more. The 176-page paperbound volume costs $9.75.

"Fish Feed Technology," published by the United Nations Development Program, contains lectures presented at the FAO/UNDP Training Course in Fish Feed Technology at the University of Washington's College of Fisheries in Seattle in late 1978.

The lecturers discussed fish digestion physiology and anatomy, nutritional bioenergetics in fish, nutritional biochemistry, the feedstuffs (components, antioxidants, toxins, unconventional ingredients, storage problems, and stability), formulating feeds, manufacturing technology, practical and novel fish diets, and quality control. The 395-page volume costs $21.50.

A Basic Textbook for Commercial Fishermen

The **"Fishermen's Handbook"**, edited by Captain W. H. Perry has been published by Fishing News Books Ltd., 1 Long Garden Walk, Farnham, Surrey, England. In four parts, the volume covers practical seamanship, safety and survival, navigation and watchkeeping and ship-handling.

Part I deals with bends and hitches, knots and splices, tackles, slings and spans, anchors and cables, and care of fish. Fishing with bottom trawl gear and seine net and bottom trawling techniques are briefly discussed. Part II includes chapters on distress and rescue procedures, visual signals, inflatable rafts, fire prevention and fighting, and emergencies at sea.

Part III discusses navigational instruments, coastal navigation, astronomical navigation, and electronic navigational aids and equipment. Part IV covers ship handling, elements of vessel stability, meteorology, international rules to prevent collisions, etc.

This is a good basic text for British commercial fishermen and others, of course, would also find much useful information in it. The 344-page book is available from the publisher for £9.75 plus £1.00 postage and handling.

Japanese Eel Culture Book Is Translated

"Theory and Practice of Eel Culture," [Yōmanho nō riron to jissai], by Isao Matsui, has been translated from the Japanese and published for the National Marine Fisheries Service and the National Science Foundation by Amerind Publishing Co., New Delhi, India. It is available (price not listed) from the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161.

The 133-page volume includes a wide range of information on eels and their culture that makes it useful to beginners, scientists, and eel culturists. Chapters discuss the position of eel culture in Japan, types and distribution of eels in Japan, life cycle of eels, elvers and their collection, feeding the eels, the proper environment, diseases and prophylaxis, pond management and culture techniques, marketing, and eel management.

Squid Fishing Areas and Trawl Obstruction Sites Listed for Atlantic Coast

The Virginia Institute of Marine Science, Gloucester Point, VA 23062, has published **"Location of Foreign Fishing Vessels Harvesting Squid in the Mid-Atlantic Region of the United States: 1970-1976"** by James Zaborski (SRAMSOE No. 235) to help U.S. fishermen locate squid resources within the Mid-Atlantic U.S. Fishery Conservation Zone. It is a summary of foreign squid fishing activities in this area, summarized from NMFS, Coast Guard, and ICNAF data. The charts show, on a monthly basis, areas where foreign vessels were engaged or were believed engaged in squid fishing, by frequency of use of the areas. Data for both *Illex illecebrosus* and *Loligo pealei* are given. While abundance and seasonal location of squid are likely to change as a result of environmental fluctuations and changes in stock size, the data remain a good tool to determine areas and times for squid fishing.

VIMS also has copies of the "Fishermen's Hang Log of the Atlantic Coast of the United States", an expanded version of a 1975 collection of data from trawler captains who charted objects or ocean bottom items that would hang or snag trawling gear and nets. The log provides as many Loran A cross bearings as possible and, when possible, converts them to Loran C. Depth (in fathoms) is given where possible.

Marine, Freshwater Fisheries in the PRC

Availability of **"Aquaculture Development in China,"** a report on an FAO/UNDP Aquaculture Study Tour to the People's Republic of China, 2 May-1 June 1978, has been announced by UNIPUB, 345 Park Avenue South, New York, NY 10010. Covered are aspects of Chinese aquaculture development, planning, and management; financing and credit; fish culture practices; integrated farming of fish, crop, and livestock; fish cultivation in natural lakes, reservoirs, and rivers; marine aquaculture; marketing; education and training; and fisheries research. Cost is $6.00 for the 65-page volume.

Also available from UNIPUB is **"Fisheries and Aquaculture in the People's Republic of China"** by G. I. Pritchard. This small pamphlet (about 22 full pages of text, 7 photographs) provides a glimpse of Chinese fish culture activities, fisheries priorities and achievements, and the Chinese perspective on fisheries science and development.

In general, marine fisheries science and development has lagged while freshwater fish culture has grown. However, the author predicts a good outlook for fisheries science and culture, particularly if coupled with the broad base of western science and technology. He also reports on Chinese studies on the production and feeding of seals and progress in artificial propagation of eels. About 60 citations of Chinese fisheries literature are listed. Published by the International Development Research Center in Canada, this booklet costs $3.50.

Editorial Guidelines for *Marine Fisheries Review*

Marine Fisheries Review publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 6, "A List of Common and Scientific Names of Fishes from the United States and Canada," third edition, 1970. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Citations

Title the list of references "Literature Citations" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, the year and month and volume and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8- × 10- inches, sharply focused glossies of strong contrast. Potential cover photos are welcome but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 1700 Westlake Ave., N., Room 336, Seattle, WA 98109.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 100 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

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